STUDENTS' PERCEPTION TOWARDS THERMAL SENSATION IN LIBRARIES

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I hereby confirm that this dissertation was the results of my own work where the use of the materials from other sources has been clearly and correctly stated with its references

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DEDICATION

This research is dedicated to Sr Raha Binti Sulaiman, my thesis supervisor and to my beloved family members:-

→ Chen Fan Heng,

→ Phang Kuen Heong,

→ Chen Sin Leng, and

→ Chen Kane Wei.

Lastly, this research is also dedicated to all my dearest friends.

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ABSTRACT

Recently, the effect of thermal sensation found to greatly impacted on the outcome or productivity of work within an area. Based on the thermal environment data, the air temperature and mean radiant temperature found to be in compliance with the standard stated, but the percentage rate of relative humidity revealed that were higher than standard, whereas the air velocity has reported were lower than standard. On the other hand, the results shown from relevant parameters in perceived thermal sensation, i.e. the level of coldness (air temperature and mean radiant temperature), the level of humidity (relative humidity) and the level of air freshness and air flow (air velocity), the major votes of these parameters were all lies within neutral thermal comfort range and no either uncomfortable feel not health symptoms expressed. The Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfaction (PPD) deduced from the perceived thermal sensation votes were in compliance with the recommended standard as well.

Besides, the predictors or variables that found to impact on the perceived thermal sensation were localized sensation body part K (Feet), the level of air flow, the level of coldness, body part E (Back) and working alone factor. Out of these parameters, the feet presented the most significant influence on the perceived thermal sensation with respect to localized body sensation parameter, whereas the level of air flow and coldness have been revealed its significance to perceived thermal sensation in respect to thermal environmental parameters. Apart from that, the productivity of work was found to be significantly correlated to level of air freshness and air flow and level of coldness, which indicating it would be influenced by air temperature and air velocity. This directly implying of the perceived thermal sensation affected the rate of productivity towards students, and the most productive of task happened when the participants were in zero perceived thermal sensation, moderate level of coldness, moderate level of air freshness and air flow rate.

ABSTRAK

Baru-baru ini, kesan sensasi haba didapati memberi kesan besar kepada hasil atau produktiviti kerja dalam kawasan. Berdasarkan data persekitaran haba, suhu udara dan purata suhu berseri didapati tidak mematuhi standard yang dinyatakan, tetapi kadar peratusan kelembapan mendedahkan bahawa adalah lebih tinggi daripada standard, manakala halaju udara yang telah dilaporkan adalah lebih rendah daripada standard. Sebaliknya, keputusan yang ditunjukkan dari parameter berkaitan dalam sensasi haba dilihat, iaitu tahap kesejukan (suhu udara dan purata suhu berseri), tahap kelembapan (kelembapan) dan tahap kesegaran udara dan aliran udara (halaju udara), kebanyakan parameter ini adalah berada dalam julat keselesaan neutral haba dan tiada rasa tidak selesa atau kesan rasa tidak sihat diungkapkan. Purata Undi Jangkaan (PMV) dan Peratus Meramalkan Ketidak Puas Hati (PPD) disimpulkan daripada yang dirasa undi sensasi haba adalah mematuhi piawaian yang dicadangkan juga.

Selain itu, peramal atau pemboleh ubah yang didapati memberi kesan kepada sensasi haba yang dirasa telah disetempatkan bahagian badan sensasi K (Kaki), tahap aliran udara, tahap kesejukan, bahagian badan E (Kembali), dan secara faktor semata-mata. Daripada parameter ini, kaki dibentangkan sebagai pengaruh yang paling besar ke atas sensasi haba yang dilihat berkenaan dengan setempat parameter sensasi badan, manakala tahap aliran udara dan kesejukan diturunkan kepentingannya kepada sensasi haba dirasa berkenaan dengan parameter alam sekitar haba. Selain itu, produktiviti kerja juga didapati mempunyai hubungan yang signifikan dengan tahap kesegaran udara dan aliran udara dan tahap kesejukan, yang menunjukkan ia akan dipengaruhi oleh suhu udara dan halaju udara. Ini secara langsung membayangkan sensasi haba yang dirasa memberi kesan kepada kadar produktiviti ke arah pelajar, dan yang paling produktif tugas berlaku apabila peserta dalam sifar sensasi haba dirasa, tahap sederhana kesejukan, tahap sederhana kesegaran udara dan kadar aliran udara.

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TC	Thermal Comfort
TS	Thermal Sensation
TE	Thermal Environment
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfaction
BMI	Body Mass Index
SMR	Sleeping metabolic rate
DR	Dissatisfaction Rate
ISO	International Organization for Standardization
EN	European Standard
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
HVAC	Heating, Refrigeration and Air Conditioning
AC	Air Conditioning
PC	Personal Computer

LIST OF SYMBOLS

°C	Degrees Celsius
clo	Clothing insulation unit
met	Metabolic rate
mm	Millimeter
m^2	Square Metre
e	*Euler's number (2.718)*
M	*Metabolism Rate*
L	Thermal Load
Ta	Air Temperature
Tr	Radiant Temperature
Rh	Relative Humidity
Va	Air Velocity

CHAPTER 1.0

INTRODUCTION

This chapter outlines the background, problem statement, research aim, research objectives, methodology, significance, scope and the overall layout to the chapter in the research.

1.1 Background Study

Recent studies have found that the effect of thermal comfort or thermal sensation has great impact on the outcome or productivity of work within an area (Ismail & et.al, 2010). Thermal comfort defined a people's psychological state of mind by referring to the feeling of too cold or too hot (ISO 7730, 2005). The indoor thermal environment parameters in room with mechanical air conditioned areas is essential to be considered for level of comfort, which would then lead to a better condition for either work or rest.

For students, library is a place where majority of their self-learning activities will be carried out here, especially for the educational institution students. During leisure hours, some of the students will visit to the library before and after the class. During assignment days, students will gather for discussion in library as well. Furthermore, most of the students will choose to study in library for the sake of peace and quiet area during the examination period. There are also many postgraduate students choose to do on their readings or writing up thesis in library.

A library is an enclosed building, the design has limited the interaction with the outdoor environment. Hence, a mechanical ventilation system or air conditioning system is important to keep the thermal condition within the comfort range. A proper mechanical ventilation or air conditioning system can help in maintaining the acceptable thermal comfort, in order to provide a satisfied and healthy environment to the building occupants.

Since there are various types of students or visitors who are having different physical background or demography status, so thermal sensation might be difference among them. The factors existed in their different physical background are, i.e. gender, age, BMI value, clothing value, working nature, being alone, etc. These factors are important in affecting the thermal sensation to the particular indoor environment (Mirrahimi S. & et.al., 2014).

Besides, the library consists of different space allocation and design in accordance to the standards and guidelines to differentiate the types of activities or particular purpose to a specific area, such as printed materials, printing, or study area. Thus, the thermal environment required for the different purpose in the particular areas needed to be taken into account.

1.2 Problem Statement

"The heat and air in the library is poor, the heat is too much, and the air is too stale and heavy", commented by a professor who has used the libraries in all around the world (Sleightholm, 2014).

"The library is so hot, which makes me distract from studying and reading, and feel very sleepy", one of the feedbacks by a student to the management of library. (University of New Castle, 2015) These thermal environment complaints have fallen for a few consecutive years.

A study on time of student is spent in a library where a place can provide the most thermal comfort environment, this enables a student can focus in his work. Recently, many complaints said that the air conditioning system in library is performing either too high or too low, this has made them to hardly could focus to their own work, this condition can be interpreted as the thermal environment in libraries was not in thermal comfort state (University of New Castle, 2015). This assessing the response on thermal sensation has become more important when it is aimed to maximise learning and productivity performances of student. Although it may not ensure to achieve high productivity with long working hours, but one thing that cannot be denied if the productivity will increase with study environment providing adequate thermal comfort. Productivity of performance for students, such as learning effect, was very much affected by temperature, this changing in air temperature might consequently demotivated the students and charged a dissatisfaction to it. Dissatisfaction with the students' thermal sensation might have possess a negative effect on the students' performance which is decreasing the learning effect (Schellen, et al., 2012).

There are parameters influence the thermal sensation which give rise in the learning productivity such as air temperature, radiant temperature, air velocity or airflow, and relative humidity. Previous studies in thermal comfort have also explained the importance of localised skin temperature involved in affecting part of the thermally comfort environment (Attia and Carlucci, 2015). Learning productivity could be affect by thermal environment with the Sick Building Syndrome (SBS) symptoms (Wargocki and Wyon, 2011). As the response of measures to the thermal environment, internal body temperature, variations of skin temperature, sweat rate/ loss, and heart rate as the most common measures is the noticeable consequences of thermal conditions. Human is sensitive to the air temperature and air velocities, especially working productivity can be increase with higher speed of airflow. Hence, air-conditioning (AC) is important to enhance human thermal comfort and working productivity in warm and humid climate. (Kosonen and Tan, 2004)

1.3 Research Aim

This research aimed to study of interactions between students as the subjects, perception on thermal sensation towards the thermal environment condition as the interface, and learning productivity as the goal, defining the students' perception on thermal sensation could lead to an effect to the learning productivity within study area, the library.

1.4 Research Objectives

The main objectives of this research are as follows:

1. To identify the pattern and effects of thermal environmental parameters on thermal sensation in library.

2. To explain the relationship of perceived responses of students to the overall thermal sensation in the library.

3. To investigate the relationship between measured and the perceived thermal sensation of students in library.

4. To recommend the most significant parameters on overall thermal sensation in library and related to learning productivity of students.

1.5 Research Methodology

This study utilized the combined method of both qualitative and quantitative statistic by utilizing field measurement and questionnaire survey. The results from field measurement will be calculated and brought to an outcome of environmental thermal sensation scale. On the other hand, students' perception responses on questionnaire will be analysed on the relationship between the variables to impact on thermal sensation and the perceptual thermal sensation will be deduced. In addition, the most significant parameters will be identified as well. From the environmental thermal sensation and perceptual thermal sensation obtained from previous analysis, a complete and comprehensive overall thermal sensation of library can be concluded.

1.6 Research Scope and Significance

This research aims to develop a mapping to identify the interactions between students' perception on thermal sensation towards the thermal environment condition that could lead to an effect to the working productivity of student in the library. Through the literature review have been done on journals, books, articles, the current studies and etc. on the general impact and relationship, and the method of practical accommodation to be determined.

This research emphasize on the significance of pattern, effect and relationship between the thermal environment parameters and students' perceptual responses to be impacted on the overall thermal sensation in library. Furthermore, the relationship between the thermal sensation and work productivity will also be determined. From the results of field measurement and questionnaire survey, the correlations between the parameters or factors to the working productivity which will be influenced by thermal environment or thermal sensation will be defined. Moreover, the demography of students will be described according to the gender, age, BMI value, and the clothing attires of student were taken into account as these characteristics will affected on the thermal sensation.

1.7 Thesis Structure

Chapter one (1) is the introduction of this research which includes research background, problem statement, research questions and objectives, brief introduction to research methodology, research scope and significance and the thesis structure.

Meanwhile, chapter two (2) is the literature review for this research. Related information from the previous research will be used as the theoretical basis for this research. These include introduction to the human factors, localised thermal sensation, thermal environment sensation factors and how the parameters would be affected on the overall thermal sensation.

In Chapter three (3), the research methodology is described in more detailed way. The ways to collect relevant data and analyse the data are outlined and discussed.

Chapter four (4) includes the analysis and the result of this research after data collection. The data gathered from field measurement and questionnaire is combined with literature review to be displayed in a more systematic table form. Meanwhile, the data collected from the questionnaire forming a stepwise correlation statistic and ANOVA method are analysed using Statistical Package for the Social Sciences (SPSS) Inc. 2009 software. The calculation and result will be included in this chapter.

In chapter five (5), discussion on this research is presented where the rationale of each obtained results is further discussed.

Chapter six (6), which is the last chapter of this research, is includes the summary of this research as a conclusion. All the research objectives are reviewed and limitations of this research are also specified in this chapter. Lastly, based on the limitations, several recommendations are given for future similar research purpose.

1.8 Summary of Chapter

This chapter gives a brief introduction of this research where the problem statement and the trigger point for this research are presented. The rationale to carry out this research is also included. Besides, this chapter had provided all the related information about this research such as the hypothesis, aim, objectives, methodology, scope and significance and the whole thesis structure.

CHAPTER 2.0

LITERATURE REVIEW

Studies have shown that human performance is very much related to thermal sensation. Air temperature is usually being the indicator for human on thermal sensation. Numeral studies, field and laboratory investigations have been carried out, and the thermal environment has its impacts indirectly on human working performance have been proven. In the next sections, thermal environment aspects will be discussed and followed by literature reviews of past researches which are focused on studies relating human working performance to the selected indoor or thermal environmental parameters.

2.1 Thermal environment

Energy flows in both building and human body is relatively a new approach to the research on built environment, as it provide a healthy and comfortable environment to the building occupants by optimizing the climate conditioning system in the building. Generally, there is a relation between subjectively assessed thermal sensation and consumption rate of human-body energy. The research show that the minimum consumption rate of human body energy that is associated with thermal sensation is close to thermal neutrality, which the point is slightly to the cool side of thermal sensation. Several studies demonstrated energy mainly been used in a building is to maintain a satisfied indoor environment for occupants, such as comfort range of room temperature, mean radiant temperature, air velocity, relative humidity, lighting and etc. Usually, energy used to maintain acceptable room temperature which is generally low within range of 20 °C to 26 °C. The relation between energy consumption rate of human body, mean radian temperature and room temperature was first explored to the prediction of the PMV/PPD model. From that, the lowest consumption of energy has been concluded occurred at thermal neutrality which is at a certain point of

(PMV=0). The research of study has pointed out the radiant heat transfer is important for human thermal comfort. The indoor thermal environment parameters and human physiological responses combined to provide thermal comfort with the lowest possible energy consumption rate of human body by ensuring the climate conditioning systems.

Besides, a study compared the results obtained from PMV/PPD model to the calculated energy consumption rate of body, which average thermal sensation of building users. This research paper verifies the thermal sensation response of subjects exposed to different indoor thermal climate parameters such as air temperature, mean radiant temperature, relative humidity, air velocity, and etc. Further studies will be required that the impact of metabolic rate on the energy consumption rate of human-body should be quantified (Mirrahimi S. & et.al., 2014).

2.1.1 Human thermoregulation

The aim of physiological thermoregulation is to maintain the core temperature within limits close to 37°C and maintain between 31 and 33°C for human thermoregulation. Human thermoregulation usually varies between individuals and within each individual, because body temperature easily get changes dynamically across the surface and within the body due to a changing thermal environment and its changing of metabolic body heat production rate. The changes in human behaviour can affect the heat balance to be restored, even though only a small amount of heat would be deficited or stored (Schellen, L. et al. , 2013).

The process of thermoregulation is controlled by the hypothalamus of the brain and/or input provided by the heat balance mechanisms which are skin receptors, and the stimulation due to blood temperature. Heat balance usually maintained by regulation of blood flow, the microenvironment will be warmer as it increases, so that excessive heat can be dissipated through the skin. During the sweating period for intensive work, the rate of metabolic heat production increases which the evaporation of sweat has absorbed latent heat providing the most efficient way to dissipate heat. Currently, the building practice has been required to follow the level of relative humidity which was controlled by technology and energy conservation, implying the difference in vapor pressure between the environment and human skin. Thus, the effective heat loss by evaporation can be prevented. During cold in contrast to the heat exposure processes, human body will contract the opposing groups to increase its rate of metabolic heat production. This is a process that its intensity can be increased until it would results in shivering in extremely cold environment or low air temperatures. Furthermore, body will responds to prevent loss of heat in a moderately cool environment by reducing heat flow to the skin. Skin is the main organ to dissipate heat out of body which a human body dissipates around 85 % of heat through the skin in moderate environment. The different body parts of skin having different thermosensitivity by Hensel (1981), so thermal sensation should be calculated by specifying at different body parts, especially in uneven surface temperature distributed spaces. According to Hensel (1981), the thermosensitivity of the skin is different in different body parts. Therefore the thermal sensation calculation should also take into account body partspecific thermal sensation, especially in spaces with uneven surface temperature distribution caused for example by windows or radiators (Schellen, L. et al. , 2013).

Depending on the heat transfer, whether heat loss or heat gain, a thermoregulation system in a human brain regulates skin temperature to balance out the core body temperature of 36.5°C. Human body will produce internal heat by reacting shivering when the condition and generate an evaporative cooling off effect on skin surface by sweating (Wang et. al, 2010). However, the thermoregulation system regulates skin temperature through vasodilatation and vasoconstriction to maintain a thermal comfort within the range of a moderately warm to a cool condition which is between 18°C and 33.5°C. This physiological principle shows that skin temperature has significant potential for evaluating thermal comfort conditions. Due to its significance, many studies have been carried out to derive a pattern for calculating a mean skin temperature. For example, skin temperature data from which the selected body segments collected, and various weight factors were considered and used to calculate the mean skin temperature (Liu, Hong et al. , 2014).

The previous study have investigated the feasibility of the evaluation of thermal sensation using the human body skin temperature. The physiological data such as skin temperature from ten body segments and overall thermal sensation could be correlated and analysed. The use of skin temperature is very significant information as an index to the thermal sensation measurement, as human body regulates skin temperature to balance out the heat gain and heat loss. Therefore, the research has depended on the experiments by using human subjects to determine and investigate how skin temperatures change, correlated to the ambient thermal conditions, and identified which parts or body segment produce the most responsive and significant physiological data that will represent the overall thermal sensation. Results of this study showed that changing rate or gradient of skin temperature of occupants became more consistent if they are in the thermal comfort state or condition, compared with the actual condition of skin temperatures of participants. In addition, the part of measured skin temperatures at their wrists generated more interpretable data, compared with all the other body parts or segments. Therefore, the research findings have shown the data of skin temperature as a thermal sensation index in a thermally uniformed environment can represent an individual's thermal sensation (Choi, J. and Loftness, V. , 2012).

Moreover, there is another more recent approaches to evaluation of thermal comfort include the adaptive thermal comfort theory, which study the adaption of people to the surrounding climatic conditions. The adaptive comfort theory propose that human will adapt their behaviour according to the thermal condition, no matter they are in conscious or unconscious state of mind, hence the thermal balance formula cannot be strictly applied. This adaptive research to thermal comfort is depend on the inherent potential of people in adapting of changing conditions in thermal environment, and is very much relied on the findings of thermal comfort's field survey. The adaptive principle has revealed that it could be delivered as "people will respond in a way to restore their comfortable if there is a change occurred which would produce discomfort to the occupants". There are different methods of adaptation to the changing environment, for instance, altering the posture, activities undergoing and the clothing level of human (Nicol and Humphreys, 2002).

2.1.2 Physiological responses

Efforts to develop a thermal sensation or comfort model have also being made in field of building and science based on reading skin temperatures from multiple body segments. There are eight and ten body segments have been chosen to study, including the head, hands, arms, legs and feet. All these studies included experiments with human subjects in environment of that generated uniform and transient thermal conditions. However, these models were mostly designed based on a statistical regression which derived a standardized formula without considering the physiological characteristics such as gender, age, body mass index (BMI) and etc. Even though biological parameters crucially affecting an individual's skin temperature and thermal sensations, however physiological parameters play a lot more important effect. Therefore, it is important to determine the body parts or segment that produces a likely to be interpretable skin temperature as a basis for estimating or calculating the individual thermal sensation of human subjects, regardless of their physiological parameters e.g. gender, age, BMI and etc. For that reason, this research conducted human subject experiments in an environmental chamber, where the thermal conditions changed from 20 °C to 30°C, in order to reach the following objectives (Attia and Carlucci, 2015).

Forehead, neck and foot cooling in hyperthermia, and its warming in hypothermia is very comfortable, even feel better than the constant conditions. The most valid cooling strategy is revealed on face part, which this affects even the other body parts' cooling sensation that are not exposed to airflow. On the other hand, the previous study also indicates the neck part is the most sensitive part if compared to face, hands and lower back. The head and hands in cool sensations and also the hands and feet in warm sensations both have significant influence on thermal comfort. These are because of the neck has high sensitivity of cold thermoreceptors concentration, while the sensitivity of hands and feet influence very much to the thermal state of the body because vasoconstriction and vasodilatation occur based on the requirement of body whether to lose or retain heat. Moreover, the hands have the most number of arteriovenous valves that control vasoconstriction vasodilatation. The hands, arms, calves and feet are found to be strongly correlated to cold discomfort, while the face and feet are strongly relevant to warm discomfort. Furthermore, the local airflows to the neck and ankles indicated as the more thermally sensitive body parts. The previous research clearly shows that the head, hands and feet are the most sensitive regions among all of the body and the design of the thermal environment that focuses on the significant impact of thermal comfort (Zhang & et.al, 2004).

As the heat generated from human body at about 75 W during sleep, and at 1000 W during exercise, the excess heat of human body will be transmitted to the surrounding environment by radiation, convection, conduction and evaporation in a precise and controlled manner. The maximum deviation of the core temperature in a surrounding environment from its standard level (Hutchison & et. al, 2015).

As point of social view, an unusual too high or low indoor temperatures cause distress or discomfort for the occupants, and they can also be related to health issues, e.g. many deaths of cardiovascular diseases are linked to excessively exposure to low indoor temperatures for long term of period. To the perspective of economic, higher occupant satisfaction and higher comfort levels in a working environment have been shadowed directly to the workers' productivity which in turns to reduce maintenance costs, as the most of the common cause of user complain is raised by thermal dissatisfaction. From the side of an environmental, the environmental impacts and resources used are associated and arose caused by the installation, production, operation and maintenance of HVAC systems in maintaining certain thermal comfort levels. Thermal comfort is very much related to the human body thermal balance, which itself will be influenced by individual and environmental parameters (Liu, Hong et al. , 2014).

2.1.3 Thermal Sensation

Thermal comfort is being described as "a condition of mind which expresses satisfaction with the thermal environment" (Marc & et.al, 2010), it is associated with subjective feeling of satisfaction experienced in achieving a balanced heat and preferable state of body in the current thermal environment aspect. In fact, people from different climates or different regions of the worlds may prefer different thermal environments who have different expectations for thermal comfort due to their state of adaptation and ability to achieve an acceptable degree of physiological thermoregulation or thermal responses. To maintain the thermal balance of human body, it will attempt its homeothermic nature by achieving some association of six parameters, such as air movement, relative humidity, air temperature, metabolism rate, radiant temperature and clothing type. Improper handling over these parameters would lead to thermal discomfort, i.e. cold feet and hands, sweating and other physiological responses of discomfort (Willem, H.C., 2006).

Normally, thermal comfort studies is using the predicted mean vote, and its subsequent relationship with percentage of a group expressing with dissatisfaction, as the development of an index (Fanger, 1970). The perceived thermal comfort was influenced by the perception, experience and cognition. Besides, thermal sense was differed from all of other senses, having a statement that "when our thermal sensors tell us an object is cold, it has already made us even colder" and human sensors were always more sensitive to changes rather than just a steady state condition. In view of these definitions, it can be said that human thermal comfort is playing a very crucial role in experience and expectation, environmental condition, sensory effect and physiological characteristics (Willem, H.C., 2006).

2.1.4 Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD)

PMV adopts six thermal comfort parameters such as surrounding air temperature, air velocity, mean radiant temperature, relative humidity, metabolic rate and clothing insulation as outputs and inputs of the overall thermal sensation of a large group of people on the ASHRAE 7-point scale. Any of the thermal sensation vote which is less than 1 or more than +1 is said to cause dissatisfaction. Hence, the vote of thermal sensation on the subjects are similar to the PMV index that is calculated for the same test conditions. The thermal sensation parameters in the PMV model that is used to fit the aim of model towards the thermal sensation response (ASHRAE 55, 2010).

Fanger's PMV (Predicted Mean Vote) method had derived for calculation of thermal comfort by utilizing international standards ASHRAE 55 (2004) and ISO 7730 (2005), where the main thermal comfort standard ISO 7730 describing "Ergonomics of the thermal environment is used for determination analytically and thermal comfort interpretation using calculation of criteria of local thermal comfort and the PMV (Predicted Mean Vote) and PPD (predicted percentage of dissatisfied) indicates that available methods for forecasting the general thermal sensation and people's thermal dissatisfaction (degree of discomfort) when one exposed to moderate thermal environments. The PMV index is the prediction of the mean thermal sensation response in respect of the ASHRAE thermal sensation scale of large group of people while PPD index measures the thermal comfort of a group of people quantitatively in a particular thermal environment (Richard, 1998).

Fanger's PMV method is running as a heat balance model, which explaining the physics of heat and mass exchanges between body and thermal environment, while human body is being viewed as a passive recipient to the stimulation of thermal environment. A human body adapts into varying conditions in the surrounding environment by thermoregulation system, and the heat balance theory applies to the assessment of thermal comfort. However, all of these does not take into account when human body that included clothing layer. In addition, PMV is less relevant with the comfort votes but focus more with the air temperature or globe temperature, and there is also a discrepancy between PMV and the mean comfort vote is correlated to the mean temperature of building (Humphrey N., 2000).

2.2 Environmental Parameters (External Parameters)

The presented approach in providing thermally neutral environments is to ensure most of the occupants thermally satisfied to the thermal comfort design. The research reveals the interaction between different parameters in generating a thermally comfortable environment. ASHRAE Standard 55 offers a 1.7 C raise in temperature where there is a 0.5 m/s growth of air velocity. In addition, Zhang et al. found that temperature that the people feel comfort when they were exposed to an air velocity of 0.20– 0.95 m/s were in 1°C higher than people were in exposing to air velocities less than 0.20 m/s. The dependency of thermal comfort and sensation of subjects also weighed to time for 4 hours in exposing to 12, 18, 22 and 28°C. Thermal comfort and sensation have reduced for all temperature except the 28°C case, this indicates transient perception of thermal comfort exists when all the comfort variables remain constant (Xiong & et. al, 2015).

There are parameters influence the skin temperature which give rise in thermal environment such as air temperature, radiant temperature, air velocity or airflow, and relative humidity. Previous studies revealed that both skin and deep body temperatures are equally promote thermal comfort. The consistent status of thermal comfort with constantly falling into the mean skin temperature have explained the importance of local skin temperature involved in affecting part of the thermally comfort environment. The localised condition appeared in body regions whereby face and chest revealed the smallest changes in skin temperature, while the hands regions showing the greatest change of skin temperature. This is due to the highly sensitivity at face and chest parts to the stimulation of thermal, it will then easily to be adapted to the peripheral temperature by maybe behavioural adjustments. Thus, the relationships between body temperature, air velocity and radiant heat load in significant thermal environments are important to generate conscious adaptation that would help in preventing large variation of body temperature through behavioural thermoregulation system (Jin, Quan et al. , 2011).

A combination of parameters including air temperature, air temperature stratification, relative humidity, radiant temperature, radiant temperature asymmetry, metabolism rate, clothing level, air velocity, and turbulent intensity in an occupied zone, generating neutral thermal sensation. There is a thermal comfort study has been carried out that 172 college-aged students as subjects averagely wore standard clothing of 0.6 clo value, and 26.3°C has been found as neutral temperature in Japan. People often interpret neutral temperature as 'acceptable' temperature in order to achieve thermally comfortable state. Furthermore, many subjects have revealed they are not only desiring for more airflow, but also the preferred air speeds are important, the air speed that is the standard of ASHRAE-55 either close to or above the 0.8 m/s. There is also a 1520-subjects survey suggested to air-conditioning (AC) area in Thailand which 26°C of air temperature, 50% - 60% of relative humidity and 0.2 m/s of air velocity to be the standard of thermal comfort (Tanabe, S. & et. al, 2015).

2.2.1 Air Temperature

The changes in indoor air temperature will influence the indoor human thermal comfort level. From the previous study, the increasing air temperature with long exposure time, the value of the ASHRAE increase which in turn cause thermal sensation decreases. From the viewpoint of design for indoor thermal environment, the effective indoor temperature defines the level of human thermal comfort. (Wan and Zhang, et.al, 2007)

Generally, the building occupants would likely and easier to accept neutral temperature, which is a neutralize effect e.g. either a cooler side in warm area, or more to a warmer side whenever in cold area. In the past review, there are more votes preferring cooler came from occupants when the air temperature is at higher than 27.0°C. In reverse, there are more occupants vote for prefer warmer when they are in colder area, and the most number of votes prefer to no change in temperature when the occupants were staying in area with temperature between 24.0-28.0°C. Definitely, the air temperature at which the most occupants have voted "prefer no change" would be assumed as preferred temperature, hence the preferred temperature would be in the range of 24.0-28.0°C. According to the analysis in this past research, when there is more than 80% of occupants felt acceptable with the preferred temperature, or even between the range of 21.5°C and 30°C, there would still raised up some health symptoms due to the existence of the other environment parameters, i.e. relative humidity and air velocity. Besides, the health symptom appeared lesser at lower temperature when the other variables remained constant, which means a lower temperature will always preferred and cause lesser thermally uncomfortable feel. (Wang et. al, 2010)

Furthermore, there are also the other results shown that people are more sensitive to the variation of temperature rather than that of relative humidity. Plus, women would be more sensitive than men to the changes of temperature. (Wan and Zhang, et.al, 2007) Although temperature has been regarded as the primary parameters in giving impact to thermal sensation, it is necessary to take account of other environmental parameters as well (Indraganti et. al, 2012).

2.2.2 Mean Radiant Temperature

The mean radiant temperature in a building defines the radiant heat exchange between occupants and the environment, promoting the similar way as air temperature but it is on convective type of heat exchange. In general, the heat discomfort occurred inside the building is related mainly with the environmental temperature and air velocity over the building, whereas the environmental temperature is included the combination effect of air temperature and mean radiant temperature. Even though the environmental temperature on thermal comfort is always straightforward, however the radiant temperature is always results in correspondent to the change of air temperature to achieve neutral thermal sensation. (Yoshida, Atsumasa et al., 2015)

In all three of the environmental temperatures, the amount of the radiant heat is needed to maintain overall thermal comfort was greatly influenced by air velocity. This relationship was extracted and it found to have a linear correlation with air velocity. When air velocities increased, it direct proportionally increased the radiant heat load. Nevertheless, the supported previous work which the thermal sensation votes by occupants were raised as the simulated solar radiation increased. When reacting to a cooling stimulus, a high frequencies of discharge will be demonstrated by cold receptor, then followed with a partial adaptation. Hence, the increments of air velocity would reflected an increase in the amount of the radiant heat, but if the air velocity was suddenly increased would cause a rapid drop in mean skin temperature, the amount of the radiant heat required would failed to be determined for maintaining thermal comfort. This experiment was the first to investigate the relationships between radiant heat load and air velocity with body temperatures in few thermal environments to determine the physiological thermal behaviour. The behavioural thermoregulation would perform based on thermal comfort and concluded that the behaviourally adjust the thermal environment are allowed to improve the tolerance for cold discomfort. (Gueritee and Tipton, 2014)

2.2.3 Relative Humidity

The effect of humidity on human thermal comfort and balance is complex, as humidity does not impact directly on the physiological responses or heat balance to the thermal environment. Humidity existed for evaporation effect on environmental and the evaporative potential of body adapts to changes. When dry heat losses are not enough to stabilize the metabolism heat produced from body, it activate the sweat glands to acquire additional cooling by evaporation (Wan, 2009).

A too low humidity may lead to irritation which the skin would become cracks and too dry. Through its impact on evaporative capacity, a higher humidity decreased the cooling potential, but the body would counteract by spreading sweat over the skin and then evaporation able to take place. A higher humidity will affect human comfort directly, while it is indirectly to the physiological responses (Liu, Hong et al. , 2014).

The past research shown the occupants would not experience any difference between relative humidity of 30% and 80% when the temperature is up to 25°C in achieving thermal sensation. At the same time, the body temperature, heart rate and sweat rate would not have any big changes as well. Only at above 25.0°C where nearer to the upper humidity, the occupants would sense the difference in thermal environment assessment. Furthermore, to the extent of higher temperatures and metabolism rate, it helps to provide with a better and a more comprehensive study on the relationship between humidity level in combination to the air temperature, air velocity, clothing characteristics, and metabolism rate (Wan, 2009).

In the relative humidity range of 40–70%, the votes of occupants that prefer "no change" are more than those preferring more humid or drier" at almost 57.9% percentage of votes. However, the votes of occupants who prefer "no change" are the same with those of "prefer drier" when the relative humidity is at around 65%. Since the relative humidity at which the most votes by occupants "no change" is said to be the "preferred humidity", so the preferred humidity range is lies between 40% and 70%. The occupants who would likely go for lower humidity at temperature of 65% may related to psychology factors. When the relative humidity is more than70%, the preferred humidity will be the range of votes for "prefer drier" (Wan and Zhang, et.al, 2007).

Relative humidity may also affect productivity, e.g. a higher relative humidity influences the perceived thermal comfort and thus affects thermal sensation. The optimal productivity is at around 24.0°C and every rise in temperature might cause the loss of productivity based on the level of relative humidity. There is a strong correlation between the productivity loss and the relative humidity which varies from description by ASHRAE. The impact of the relative humidity is higher when the neutral temperature is higher, consequently the productivity loss would be increased which mean a decrease in productivity occurs (Clements & et.al, 2000).

Obviously, there are many other parameters that would affect human thermal comfort, especially the air velocity. However, the effect of air velocity may be taken over by humidity for a better achievement in thermal comfort. The increment in indoor air temperature needs to be assisted with reducing the indoor humidity level to achieve greater thermal sensation among the building occupants. (Yoshida, Atsumasa et al., 2015)

2.2.4 Air Velocity

Besides, wind speed which is also airflow has been indicated as a better predictor to the thermal environment amidst of all the parameters defining thermal comfort. When confronting airflow, radiant heat was needed to maintain the overall thermal sensation and thermal comfort to be higher at resting mode compared to during exercising. During exercising, the body temperature is consistently rising to avoid peripheral vasoconstriction which in turn to maintain the skin temperature at higher point than at resting mode. The strength of radiant heat is required to achieve the overall thermal comfort that is relevant to air velocity. When the air velocity increased, radiant heat load received by subjects would be increased as well. The cold receptors will discharge with high frequency, in response to cooling stimulation, it will then consequently partially adapt to the temperature to lower down the transmitting signal.

Hence, the increment of wind speed would cause a rise of the radiant heat intensity, and it would later on be lower down (Ugursal, A. and Culp, C. , 2013).

A dynamic airflow and localized airflow has made a significantly big differences in thermal sensation and thermal comfort. Few researches concluded that higher power of dynamic airflow with high intensity of turbulence and varying air velocities tend to generate cooler effect than constant airflow. Adaptation of skin thermoreceptors to the airflow conditions can be reduced by dynamic airflow and the turbulence intensity improves the coefficient of convection coefficient, hence the better convective heat loss on skin surface. There are studies also showed that the overall thermal sensation of people will be influence by the localized thermal sensation at thermally sensitive regions of the body, whereby the neck, body, hands, feet and head are the most sensitive regions (Jin, Quan et al. , 2011). Besides, the previous studies showed the effect of dynamic airflow is closely relevant to the localized cooling on thermal comfort, which these combination on the cooling effectiveness will be referred to as the Dynamic Localized Airflow. By producing a dynamic airflow and focusing it to the thermally sensitive regions of the body tends to increase cooling sensation with a reduced amounts of airflow as lesser air is needed to cool a relatively small region or parts of body (Ugursal, A. and Culp, C. , 2013).

The airflow was directed with less amount of air to the specific parts or locations of the body to enhance the cooling sensation. Previous studies results in that people need more air even when they are in cold thermal sensation. The results show the preference of people on the airflow as a parameters of thermal sensation which there only 42% of all the time people have demanded less air when they are in cold environment. Hence, these indicated people's preference on thermal sensation is airflow. The fact is that more airflow speed up the process of heat loss and enhance better cooling thermal sensation which making the person feel cooler. There are some tests were carried out in the hot and humid region with pleasant feel of airflow of the United States. Moreover, subjects have showed a positive responses towards airflow during in this type of hot and humid region. The overall results revealed the preference of high metabolism rate of subjects who are thermally uncomfortable would go for more airflow even when the subjects were in neutral or colder thermal environment. In addition, the average air velocity for the head, hands and feet was at 0.22 m/s while the ait velocity of 0.28 m/s only for head cooling. In addition, there are only 4% of subjects have expressed dissatisfaction with the airflow which much different as Standard 55 (2004) predicted (Chludziaska, M. and Bogdan, A, 2015).

There is another main variable in study of thermal sensation is the location or parts of the airflow on the body. The study has been hypothesized the more airflow at the head level in producing a cooler thermal sensation would be more effective than the concurrent (not localised) airflow. The results of thermal comfort and thermal sensation are different in this case, as in concurrent airflow generates lower thermal sensation but higher thermal comfort votes. The concurrent airflow with 2.13 Met of thermal sensation votes while the no localized airflow condition with 1.55 Met. The only difference with the different airflow mode would be caused the changing in metabolic rate, e.g. concurrent airflow yields a higher metabolism rate. However, the head only airflow is not effective in dissipating the additional heat produced by the high metabolism rate, this indicating the thermal comfort votes of the head only airflow were almost similar as the no air condition (Ugursal, A. and Culp, C. , 2013).

Previous research on the airflow influence on thermal comfort provide that building occupants desire more airflow and 60% of the building occupants feel that airflow enhances their ability of work, while only 15% feel that airflow have disturbed with their productivity work. Besides, there are almost double as more people preferring more air movement than the people that prefer less air movement. Varying the air-flow speed in the occupied zone is a viable strategy to overcome this problem. There are studies also showed that dynamic airflow generates a better cooling sensation than uniform airflow (Chludziaska, M. and Bogdan, A, 2015).

2.3 Human Factors (Internal Parameters)

2.3.1 Gender and Age

It is hard to meet the needs of everyone to be thermally comfort, due to the huge difference between people, both in psychologically and physiologically adapt to the condition. There are some researches showed a discrepancy between the actual thermal sensation and PMV, which are caused by gender and age, even though a good agreement between the actual mean votes and PMV has been found in mechanical conditioned buildings.

By referring to Fanger, males and females would have similar preference of thermally neutral temperature, with regards to same boundary condition to attain thermal comfort. However, other results showed that women particularly have higher thermoneutral zone compared to men, and more than half of her studies showed that females delivered the more dissatisfaction in thermal comfort than males where the same thermal environment provided. This is because sensitivity of females to the fluctuations of surrounding air temperature more than the men. Hence, the emphasis of differences on gender have revealed the thermal perceptions between males and females are significantly differ the thermal neutral and thermal comfort conditions (Schellen, et al., 2012).

The research survey results have divided to two gender groups, basically males and females group. For males group, the outcomes describe the males are more sensitive to the change of air velocity, while females group were found to be more sensitive to the change of air temperature. The neutral temperatures at velocity of 0.1 m/s for males and females group were indicated to be at 24.5°C and 25.9°C, thus it showed that male subjects is 1.5°C lower than female subjects, which have drawn up the gender differences in thermal sensations. Moreover, it could be found that females prefer higher temperature than males, when the same air velocity offered, a gender difference of 0.3°C to 0.8°C air temperature has been found (Schellen, et al., 2012).

The skin temperature of females were slightly lower, but the higher mean core temperature of females compared to males. As to the extend of the difference between localised body parts of males and females, the temperature of the arms and hands differ largest between the two genders, whereby majority of females have the significantly lower local skin temperature. Females tend to have significant cooler sensation compared to men. However, a higher possibility of females feel unacceptable to the thermal environment, with comparison to the males. The hands location of males were found to have the highest temperature from the localised body temperature. The results show a significant effect on the productivity of males were lower during thermally comfort period if compared to females (Choi, J. and Loftness, V. , 2012).

2.3.2 Clothing Level

For an average of clothing level of 0.55 clo and 1 met activity level, the greater effect of increased air velocity at higher metabolism rate, in order to reduce the skin temperature. At the same time, a lighter clothing level will enhance the skin exposure to the air velocity effect, which would generate 'freshness' that would likely to contribute to psychological sense of thermal comfort. By removing or adding clothing layers, or altering body position to counteract the rise or drop of body temperature, or to maintain the mean body temperature, so that the thermal comfort could be achieved (Liu, Hong et al. , 2014).

2.3.3 Metabolism Rate - Physiological Parameters

Under a dynamic localised airflow condition and in neutral and warm temperature, transient metabolism rate has conducted a thermal comfort study. The existence of airflow is potential to rectify discomfort in high metabolism rate and warm temperatures conditions (Ugursal, A. and Culp, C. , 2013).

Body Mass Index (BMI) is an indicators of direct measures of body fat ratio, the formula is as below Equation 2.3.3. It gives off an impression to be as strongly correlated with different metabolism and disease results similar to more direct measures of body fatness. Basically, BMI gives off an impression technique of screening for weight classification, for example underweight, normal or healthy weight, overweight, and obesity in accordance to gender, as shown in Figure 2.3.3a and 2.3.3b.

Equation 2.3.3: Formula for calculation of BMI rate.

Body Mass Index (BMI) = $\frac{weight\ (kg)}{height^2 (m^2)}$

Sleeping metabolic rate (SMR), is entangled and has been concentrated on in distinctive viewpoints by different researchers. Different researchers have reported contrasts in metabolism rate between the different sleep stages, and the total sleep time has influences SMR. Nonetheless, we know about no studies to date of how SMR changes with body weight, body mass index (BMI) or body composition. The present study was intended to figure out if the obese and non-obese people for SMR, the reduction in SMR in connection to body weight, and BMI, and the proportion of SMR to RMR at different time periods during sleep. Lower SMR toward the end of sleep may be an extra marker to consequent an increase of weight. A solid and very critical correlation between SMR and BMI are revealed. SMR reduces during sleep as a greater function of BMI to be increase (Zhang K. & et.al., 2002).

Previous studies recorded the importance of metabolism rate on draft dissatisfaction of group of subjects. The results are aligned with 5% Dissatisfaction Rate (DR) for low, 4% DR for medium, and 3% DR for high metabolism rate conditions. This is due to the mean air velocity is an average of varying airflow rather than uniform airflow being stimulated by the body. The preferences of airflow were consistent with the mean air velocities in which varying airflow is more preferred, which is inversely related to more airflow (Ugursal, A. and Culp, C. , 2013).

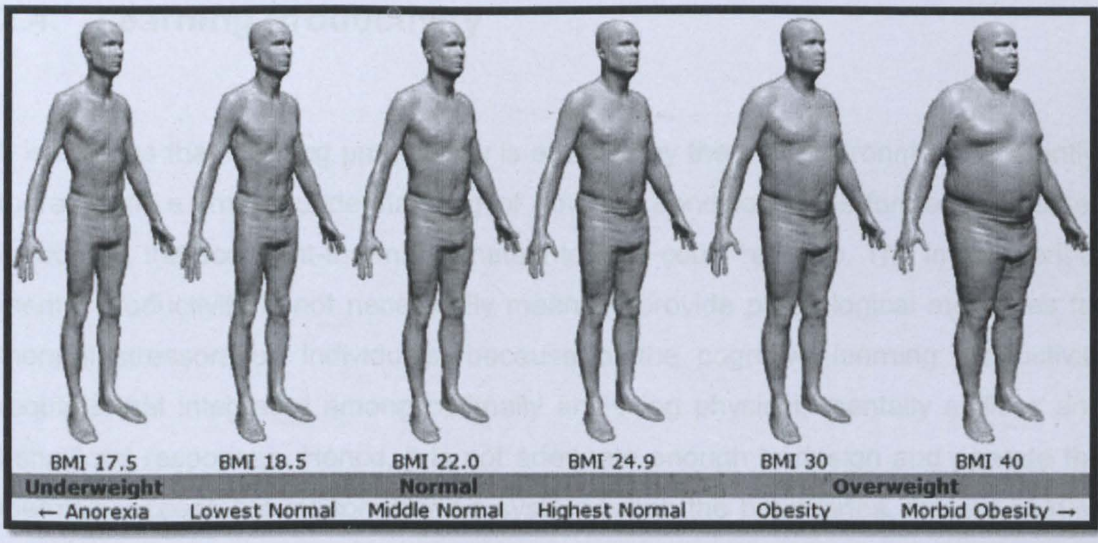

Figure 2.3.3(a): Classification of BMI Group for Males.

(Source: Retrieved from: http://www.scientificpsychic.com/fitness/diet.html .)

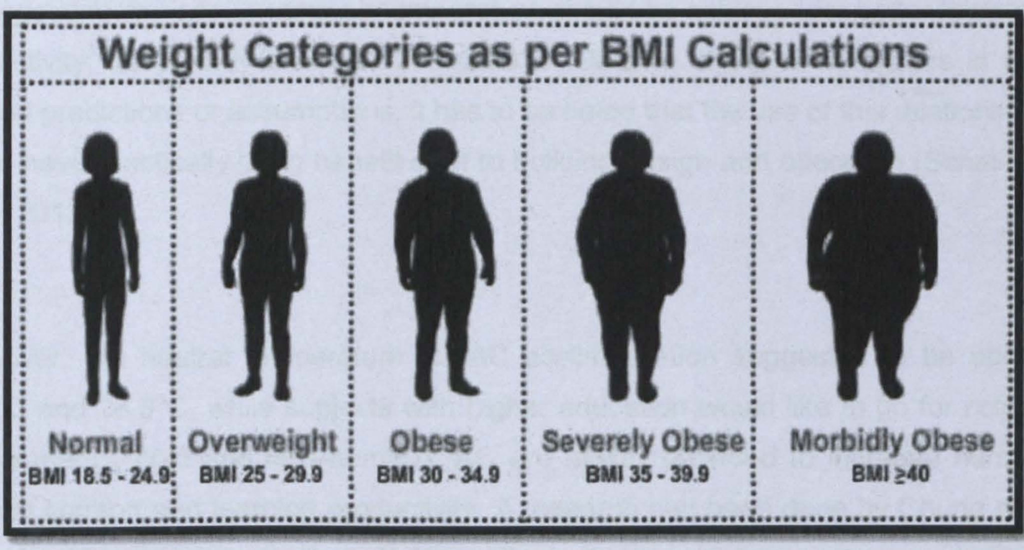

Figure 2.3.3(b): Classification of BMI Group for Females.

(Source: Retrieved from: https://metabolicmemory.wordpress.com/category/weight-loss-fitness-research/ .)

2.4. Learning Productivity

It is obvious that learning productivity is affected by thermal environment. Currently, there is still a limited understanding of how the condition in performance-oriented outcomes, the occupant-thermal climate interface could result in. The impairment of mental productivity is not necessarily meant to provide physiological measures for thermal stressors on individuals, because of the cognitive learning productivity requires that integrated among optimally achieving physical, mentally abilities and behavioral responses. Hence, it is not adequate enough to design and operate the thermally acceptable air conditioning system within the boundaries. Recent studies have indicated that thermal conditions leading to comfort may not results in an optimum productivity and findings have reviewed that learning productivity could be affected even only a moderate thermal stress (Schellen, et al., 2012).

The air temperature up to 23.0°C is potentially benefited learning productivity while further increase beyond 24.0°C could lead to bad effect in productivity, the slope and its 90% confidence interval seemed to suggest that to be available. This results meant in suggesting that cooler room air temperature should be achieved for better learning productivity, particularly between 20.0-23.0°C. Despite of the uncertainties in the derived predictions or assumptions, it has to be noted that the use of this relationship would have practically bring benefit a lot to building design and operation (Schellen, et al., 2012).

Moreover, the neutral temperature for AC acclimatization suggested to be about 25.4°C and 26.3°C, while subjects with higher education would like to go for colder environment (cold and less-humid). AC are mostly provided to increase human thermal comfort and learning productivity. A research had been done by Chung and Tong for 134 university students in Hong Kong, the neutral temperature at clothing level of 0.6 clo and estimated air speed of 0.1 m/s was found at 24.9°C. This evaluated the learning productivity of neutral thermal sensation of subjects with normal office clothing and well-conditioned environment, while the energy used was not a concern in this case. However, there are still possibilities to save energy, e.g. sustainable design of building with well-planned of AC arrangement, encourage a lighter clothing for occupant to be dress on, enhance air movement, and many mores. Since productivity is correlated to occupants' thermally satisfaction, a preferred air velocity without any disturbance is a crucial factor. Besides, younger population nowadays enjoyed AC excessive cooling very much, especially who have grown up in urbanize environment. The main things to be examined is the thermal sensation of subjects in the summer AC environment, and also find out the parameters for improving the thermal comfort with minimum use of energy, which are air temperature, relative humidity and air velocity. From the survey, the major subjects were young educated adults, have recommended an environment with controlled AC and higher airflow velocities. A general improve of air movement over the occupied area would cause the occupants to work well and enhance human comfort, even at a higher air temperature (Chow T.T. et al., 2010).

2.5 Thermal Sensation in Library

2.5.1 Spaces Distribution

There are sizes or areas specified for the functional spaces in accordance to the type of library. Different type of libraries would have to bind with different design and facilities required to meet the needs of library occupants. Generally, an academic library is a place served for students to study and do research, usually it can be known as research libraries and commonly found in college or university area. Thus, when designing academic libraries, the design team is to incorporate the criteria of comfortable, quiet and adequate area or space into planning. As library often been used to collect and store printed materials, there are also varieties of audio, visual, and the other types or forms of media collections which usually found in academic libraries (Organ, M. and Jantti. M. , 1997).

The facilities in a library should be arranged it well, as a well-planned facilities design would allowed an adequate, private and secure space, provided to enhance learning productivity of students, by referring to the Association of College and Research Libraries' Standards (ACRL). An appropriate or well-planned indoor environment design with adequate services, resources and facilities equipped could lead to conduciveness in learning, study and research (Ala, 2015).

There are different type of functional spaces that usually would be included in the design of the academic libraries (Wbdg, 2015). According to the Whole Building Design Guide, the listed functional spaces of an academic library are as follows :-

I. Spaces for Collection

This space is an area to store the collection of printed materials e.g. dissertation, reference books, fictions books and etc. Since there are bundles of printed materials available, thus the arrangement of shelving in present academic library must be flexible. The fluid movement between these book shelve spaces would contribute to the ease of rearrangement of book shelves due to the libraries would continuous update their materials.

II. Spaces for Multimedia and Electronic Workstation

This space is an area provided for the student to search for the electronic data e.g. e-books, e-journals, and etc.; and multimedia data such as videos, images, maps and so on. Since the electronic data and multimedia data are available and free for student to access, thus the sufficient space of data access facilities i.e. media storage, information system and facilities should be allocated in academic library. Furthermore, the information and media system should always keep updated in library programme and associated within the computer services in campus.

III. Spaces for Audio-Visual Rooms

This space is an area provided for the student to play the audio and visual data, at the same time students can discuss and study from the audio or visual data. This facilities focused to aid students to absorb the information more effective, because brain would function better with audio and visual-guided, rather than depend solely on listening or reading.

IV. Spaces for Seating

This space is an area particularly for the students to have their own and secure space, table and seat are provided. Students can put their books or laptop on table and bags or belongings can be placed within their area. This would create a sense of privacy, security and comfort for students towards the surrounding or environment.

V. Spaces for Meeting and Discussion

This area of space allowed the students to meet up and discuss about their research or group works. The meeting and discussion area usually is isolated from the study area which required to be stay quiet, it will be located at those area are provided for student can talk and discuss without disturbing or isolated from the other areas.

2.5.2 Design Considerations

In the recommended set in the General Library Space Allowances, the space size projects for facilities in each of three library system size classifications are listed. These are not authoritative space programs, but rather advisers for speculated space sizes prescribed for the given size facility. These contemplations may influence the functional ranges and spaces incorporated into the project and their relative sizes. For example, reading area at around $1672m^2$ will need to provide with $84m^2$ of reading space including tables and seats as shown in Figure 2.5.2 (Organ, M. and Jantti. M. , 1997).

LIBRARY SPACE ALLOWANCES

	Facility Size Category	SMALL			MEDIUM			LARGE		
	Category Population	up to 4000			4001-12000			12001 and above		
	Population (this example only)	4,000			12,000			26,000		
	Planning Factor (Formula)	Units (holdings, #seats, # staff, etc.)	Square Meters	Square Feet	Units (holdings, #seats, # staff, etc.)	Square Meters	Square Feet	Units (holdings, #seats, # staff, etc.)	Square Meters	Square Feet
	Auth per AFH 32-1084		743	8,000		1672	18,000		2787	30,000
	This Example		743	8,000		1672	18,000		2787	30,000
Public Services										
Circulation Desk	Staff areas times 150sqft	2	28	300	3	42	450	4	56	600
OPACs/ILS	1 OPAC = 30sqft	3	8	90	8	22	240	12	33	360
Reading Areas (tables & carrels)	30 sqft per seat	20	56	600	30	84	900	60	167	1,800

Figure 2.5.2: The General Library Spaces Allowance Table for Reading Spaces.

(Source: Organ, M. and Jantti. M. , 1997)

I. Public Services Areas

The fundamental parts of all library facilities are people in general administrations principally address materials and assets for grown-ups, including collection spaces, reading areas, computer terminal spaces, and administration work areas. Development and extension ought to be added to these limits, as required. The genuine size of the general, reference, and unique collection spaces and the relative size of every kind of gathering may change significantly from library to library.

II. Information Services Areas

Data administrations comprise of PC workstation regions, PC labs, hardware, and related framework, as required. PCs accessible for patron use are the essential segments of the data administrations ranges. On the off chance that the library is to be gathered with the BEC, consider the requirement for a PC lab that may be shared.

III. Reading Area

Reading areas are made out of major and minor perusing spaces. Most of the places ought to be situated in the main space of people in general administrations spaces. Minor perusing spaces, containing some bit of the reading area, may be scattered about in semi-remote areas for private perusing or genuine study. Electrical outlets and data ports are provided for tablets and other hardware in the floor at every perusing station.

The area of spaces are conformed to the proposals of the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). Outline building HVAC frameworks to suit long haul adaptability, addition and renovations. Considering the effect of PCs and solar space heating systems on the HVAC plans in future as well (Organ, M. and Jantti. M. , 1997).

2.6 Literature on Standard and Regulations

Thermal comfort standards assist designers with establishing indoor conditions that suit building occupants' desires. In hot atmospheres there are no present benchmarks or standards that characterize what those "comfortable" ranges or conditions that ought to be in building. In the meantime, the accessible models worldwide are mostly centred around office structures, incompletely in view of the set number of reviews in the territory of building. Late principles depend on Fanger's PMV model for fixed aerated and cooled structures and versatile models for normally ventilated structures. Moreover, the western world standard aren't fitting for some nations, particularly hot atmosphere zones, and a redesigned global standard for thermal comfort is required. Accordingly, the biggest issue in this discourse remains the relevance of those benchmarks and models of none mechanical air-conditioned structures in hot atmosphere buildings (Lomas et.al., 2012).

I. EN ISO 7730

Taking after the advancement of mechanical air-conditioned, the business group has been more disposed towards simulated indoor situations and fixed structures. In light of atmosphere chamber tests, Fanger's Predicted Mean Vote (PMV) model of thermal comfort, initially settled a connection between six essential parameters in view of thermal balance equation under unfaltering state conditions. The model has been fused into various standard and design codes. The model is planned for application to circumstances like those of fixed mechanical air-conditioned structures. In these sorts of structures, the envelope is totally fixed with non-operable windows and tenants connect with a simulated indoor environment completely disengaged from the outside one. Scientists have proposed that the PMV-model ought to just be utilized for fixed mechanical air-conditioned building . In any case, the PMV-model is ordinarily connected in the configuration of air-conditioned office structures in hot atmosphere zones (Lomas et.al., 2012).

II. ASHRAE 55

Keeping in mind the end goal to locate a distinct option for the PMV-model, in 1995, ASHRAE yielded a study which concentrated on measurable examination of high ended information from existing building instead of the warmth equalization methodology got from atmosphere chamber information. The information was gathered from 160 uninvolved, dynamic and blended mode office structures in various atmosphere zones, including those considered hot moist and hot dry. The occupants demonstrated a low affectability to indoor temperature changes (Richard, 1998). The slope of their warm sensation votes regarding indoor agent temperature ended up being 1 vote in favor of each 3°C to 5 °C change in temperature. The clear acknowledgment of hotter temperatures is thought to be because of diverse psychological perceptions and adaptations (Lomas et.al., 2012) Occupants often either adjust the encompassing environment to suit their desires by using windows, blinds, fans, and doors; or shift their thermal temperature by various physiological thermoregulatory system; changing metabolism rate and clothing value (rate of heat loss) (Lomas et.al., 2012).

The 6 parameters ought to be looked into. However, a suggested appendix in September 2008 recommended the utilization of the PMV model to air velocities beneath 0.20 m/s. Air velocities that is greater than this may be utilized to increase the air temperature breaking points of the safe place in specific circumstances. This could be accomplished by utilizing the fans to increase the air velocity to balance expanded air and radiant temperatures. In any case, if the relative humidity is high but the mean radiant temperature is low, increased air velocity is less successful. The required velocity for light, fundamentally sedentarily exercises will not be higher than 0.8 m/s (Lomas et.al., 2012).

III. Environmental Guidelines for the Storage of Paper Records 1995

The environmental factors, temperature and relative humidity are vital components that would influence human and printed material in a library. Since temperature and relative humidity as often as possible are reliant in their impacts on paper, they are dealt with together. The degradation process of paper is estimated indirectly through alteration in physical properties.

A scientific relationship has been developed between response rate and the proportional of the absolute temperature to identify the influence of temperature and relative humidity on degradation rate. The relationship has demonstrated with data from several temperatures, an ascertained activation energy, which is the threshold energy to bring about sub-atomic changes or reactions. From information on the physically and chemically tested paper at different temperatures, activation energy could be achieved. The data were created along these lines, expecting a relative response rate of one at 70°F (21°C) and 50% of humidity level. Relative humidity does take into account in calculating activation energy but the values of relative degradation rates can be estimated at other relative humidity values. (Wilson W.K., 1995) At further studies, the air temperature suitable for archival storage or library is at around 15°C - 25°C (specific in 21°C) and at relative humidity level of 50-60%. (Canadian Council of Archives, 2003)

Environmental Standards Overview			
Media	**Standards or Guidelines**		**Reference**
	Temperature	**Relative Humidity**	
Paper Archival, textural, library materials, cartographic media Prints, drawings	Combined stacks and user areas 21°C max. +/−2°C	30–50% +/−3%	Wilson (1995:2)
	Stack areas – access and retrieval only 18°C max. +/−2°C	30–50% +/−3%	
	Stacks – optimum preservation 1.7°C – 18.3°C +/−2°C	30–50% +/−3%	
	Storage 15.5°C – 18.3°C Occupied 15.5°C – 23.8°C	40–45% 40–45%	Lull (1995:7)

Figure 2.6: The Standards Level of Temperature and Relative Humidity for Archival and Library Materials Storage Area.

(Source: Canadian Council of Archives, 2003)

Table 2.6: The Comparison of the Standards, Regulations or Guidelines that Relevant to Thermal Comfort and Library Material Storage Area.

Standards		ASHRAE Standard 55 (1992)	ISO 7730 (1994)	Environmental Guidelines for the Storage of Paper Records (1995)
Category/ Uses		Light, sedentary activity	Light, sedentary activity	Libraries & Archival Storage Areas
Indoor Climate Conditions	Ta (°C)	23.0~26.0	23.0~26.0	15.0~25.0
	Tr (°C)	23.0	-	-
	RH (%)	20~60	30~ 70	50~60
	Va (m/s)	0.15	< 0.4	-
	PMV	-0.5 ~ 0.5	-0.7 ~ 0.7	-
	PPD (%)	< 10	< 15	-

2.7 Conclusion

The focus on effects of thermal environmental parameters in comparison with the standards, which is air temperature, relative humidity, radiant temperature, and air velocity, on the human physiological response and perception on thermal sensation. Furthermore, the human factors cannot be neglected, e.g. the gender, metabolism rate, and clothing level. The condition of experiment for the parameters of thermal environment that found to be crucial factors from my literature study were set up in the field studies where having specific and similar conditions, this helps the settings and conditions resulting in better evaluation of relevant response between the measured parameters and the independent variables.

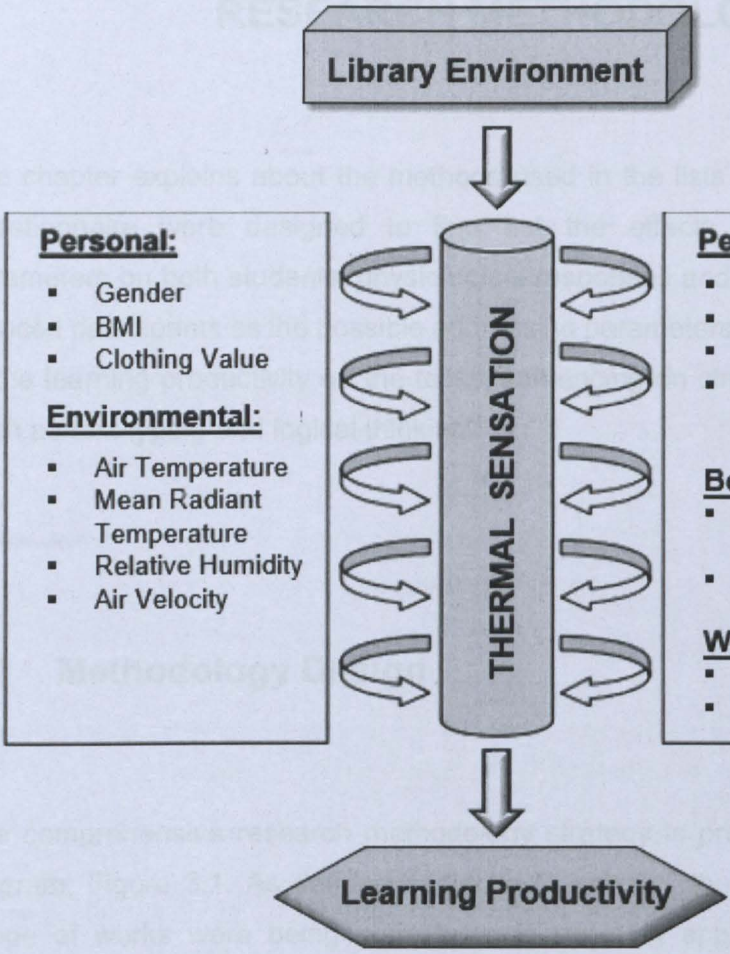

Figure 2.7: The Conceptual Framework in Developing Thermal Sensation Model Towards Thermal Environment.

CHAPTER 3.0

RESEARCH METHODOLOGY

The chapter explains about the methods used in the lists of field study and survey questionnaire were designed to find out the effects of thermal environment parameters on both students' physiological responses and perceptions of thermally-induced participants as the possible addressing parameters that could affect students in the learning productivity on the tasks, influencing on simulated assignment tasks such as text-typing and logical thinking.

3.1 Methodology Design

The comprehensive research methodology strategy is presented in the schematic diagram, Figure 3.1. As defined earlier in Chapter 1, the research objectives and scope of works were being considered in deciding appropriate method for field measurement and questionnaire survey to collect required data. Further evaluations and discussions will be delivered in the following sub-sections in this chapter.

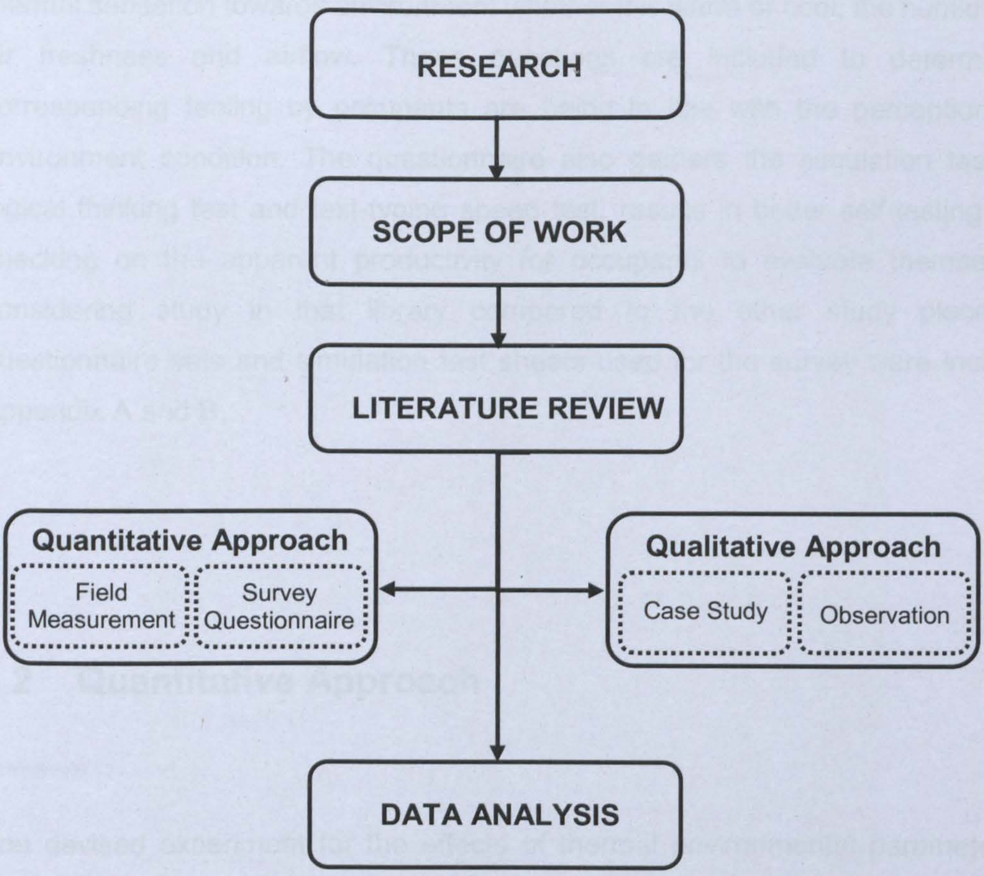

Figure 3.1: Process Flow of Research Methodology Strategy

Thermal sensation study includes two essential groups of data which are quantitative approach and qualitative approach data. The quantitative approach associated with the field measurement and questionnaire survey in order to gather the data of thermal environment and participants' responses towards the thermal sensation. On the other hand, the qualitative approach taken account into case study area descriptions and observation, undertaken inspection on overall characteristics and data of environment and participants that are to be considered as essential to correlate measurement of thermal environment, human personal factors, perception, behaviour and background.

The data collection towards thermal environmental measurement is working simultaneously with questionnaire survey which included some standard questionnaires (response scales) for thermal sensation studies i.e. ASHRAE 55 thermal comfort scales. There are some questions involved occupant's self-evaluated thermal sensation towards environment whether it is warm or cool, the humidity level, air freshness and airflow. These questions are included to determine the corresponding feeling by occupants are being in line with the perception of the environment condition. The questionnaire also gathers the simulation tasks' e.g. logical thinking test and text-typing speed test, results in better self-testing or self-checking on the apparent productivity for occupants to evaluate themselves, in considering study in that library compared to the other study places. The questionnaire sets and simulation test sheets used for the survey were included in Appendix A and B.

3.2 Quantitative Approach

The devised experiment for the effects of thermal environmental parameters was conducted during the autumn semester of the University in Main Library and Za'ba Memorial Library of University of Malaya. This two case studies have been chosen to execute the thermal environment parameters measurement and questionnaire survey simultaneously. Observations and readings of instrument were taken for one week in each of the case study area.

3.2.1 Field Measurement

The selected equipment employed for the field survey of this research was Delta Ohm HD 32.3. This equipment is ought to be accurate and was placed at 1.0 m from floor level during the field measurement period. The Delta Ohm instrument is subjected to test accurately, and complied with CE comformity which has underwent a series of standard tests. Delta Ohm HD32.3 is aided with probe TP3276.2, HP3217.2R, and AP3203.2 to be able to detect the Globe Thermometer Temperature, Tg; Air temperature, Ta; Mean Radiant Temperature, Tr; Relative Humidity, RH; and Air Speed, Va. Furthermore, the software of Delta Ohm provided also with the graphs of analysis, and PMV and PPD index which conform to the ASHRAE guideline. (Delta Ohm)

Figure 3.2.1 (a): The Delta Ohm HD32.3 Model Used in this Research.

(Source: Field Study, 2015)

The settings of thermal environmental parameters, which is air temperature, relative humidity, radiant temperature, and air velocity were cautiously been observed until the conditions were in stable state. Environmental parameters such as air temperature, relative humidity, mean radiant temperature and air velocity were measured simultaneously when students were filling up the survey questionnaire. The Delta Ohm built with combined temperature and relative humidity probe (air temperature and relative humidity), temperature globe (mean radiant temperature) and omnidirectional hot wire probe (air velocity) were used to obtain the readings for environmental parameters. The Delta Ohm instrument was placed on a table, with respect to the standards and regulations in measurement rules. During the experiment, the instrument was placed to avoid the body temperature of occupants would directly affect the reading.

The field study for this research is adopted to Class II measurement protocol as shown in Table 3.2.1 which is assisted in collecting basic environment condition and personal parameters, this can simplify and quantified the data analysis by converting it into different thermal indices.

Table 3.2.1: Three Classes of Measurement Protocols for Thermal Comfort Field Measurement.

Class	Measurement protocol	Result description
I	All sensors and procedures are in 100% compliance with ASHRAE Standard 55. Simultaneous three heights of measurement (0.1, 0.6 and 1.2 m). Laboratory grade instruments: include fast response omni-directional anemometer capable of turbulence intensity assessment.	Effect s of non-uniformity (asymmetrical) in the environment Suitable for detail examination of localized discomfort (in air-conditioned spaces)
II	Measure all physical environmental variables (air temperature., mean radiant temperature, wind speed, relative humidity, clothing, and metabolic rate) At one height of measurement (0.8-1 m) Data is sufficient to calculate PMV, PPD indices and at the same time and place (location) thermal questionnaires are ministered	Allows an assessment of the impacts of behavioral adjustment and control on subjective responses. Data can be converted to different thermal indices such as operative temp, ET, and SET.
III	Simple measurement of indoor temperature and possibly humidity. At one height above the floor Possibly asynchronous and non-contiguous physical measurement (temperature) and subjective assessment (questionnaire).	Data does not necessarily allow explanatory analysis. Widest range of published data. The majority of field studies used in the derivation of early adaptive models.

(Source: Brager et. Al 1998)

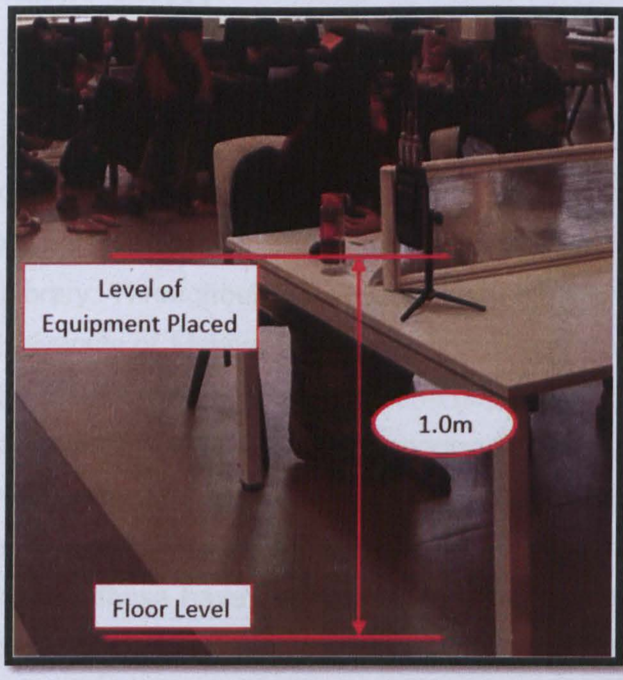

Figure 3.2.1(b): The height of Delta Ohm equipment had been placed from the floor level in Main Library, University of Malaya

(Source: Field Study, 2015)

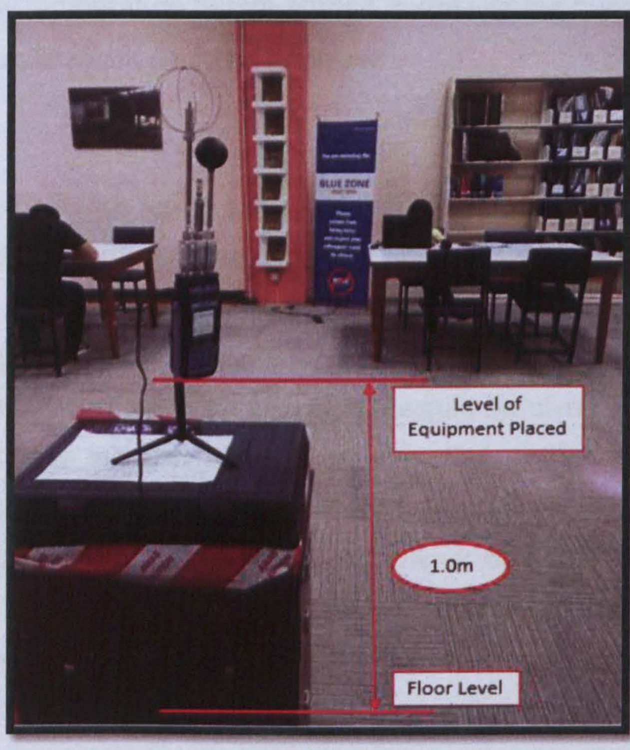

Figure 3.2.1(c): The height of Delta Ohm equipment had been placed from the floor level in Za'ba Memorial Library, University of Malaya.

(Source: Field Study, 2015)

3.2.2 Questionnaire Survey

In total, one hundred and eighty eight responses of student subjects were collected from two hundreds sets of questionnaire were distributed, there are one hundred and six responses collected from Main Library, and eighty two responses gathered from Za'ba Memorial Library. Throughout this survey, these participants were adults and students of the University of Malaya (UM) who have responded to the survey form within that specific case study area. In overall, the physical condition of the subjects for both case studies were normal, without appearing health problems or illness e.g. fever or headache. The subjects chosen were studying or either working with their assignment tasks, hence they were either performing logical thinking tasks or text-typing works, which all these have been provided in survey form as choice for the nature of their working task. The subjects were chosen to go through the survey, must have stayed in the environment within that case study area for at least 15 minutes and above. This is to make sure that the body temperature were in stable state and prevent from disturbances or inaccurate data for thermal sensation survey. If the subject was just came in from outdoor environment or another type of thermally unsatisfied environment, the subject would have to rest and stay for 15 minutes to stabilize the body temperature before started to answer the questionnaire survey, so that a more accurate result could be analysed.

The survey questionnaire forms were divided to two sessions in each of the case study area, which were morning session and afternoon session. This is because the level of thermal sensation in the morning session was different with the afternoon session, as the contrary with the outdoor temperature of two sessions. The subjects who were working within the case study area would be given questionnaire survey. Survey activities were initiated 10 to 20 minutes. Before the test or survey begin, it has be made sure of the subjects have stayed within the case study for at least 15 minutes. Once the current nature of subject's work had been clarified, the subject would be given a relevant designated simulated self-checking test and the results would be recorded as backup. The subject would then need to proceed to complete the set of questionnaire. The gender and age information of each subject was recorded, and the weights and heights were also calculated as a basis for estimating the body mass index (BMI). All the physiological, physical, overall thermal sensation and learning productivity measurements data were recorded and performance folders were collected and organised.

Details of Questionnaire Survey Forms

The participants were asked to complete a set of questionnaire comes with a designated simulated task throughout each survey session. The questionnaire set was implemented into four sections, which comprises of:

a) General Information, personal information data such as gender, age, height, weight, and etc. would be collected in this section.

b) Clothing Attire Analyse Form to record down their clothing level.

c) Localised Thermal Sensation at their forehead, front and back sides of neck, chest, upper arms, lower arms, back, hands, thighs, calves, and feet.

d) Thermal Comfort Survey describes the overall thermal comfort, and self-assessed effort and productivity.

Measuring learning productivity of a student is hard and would bring into controversial due to the dynamisms and complexity of tasks and activities. It is not the scope and purpose of the laboratory experiments to address any extraordinary questions, e.g. how thermal environment affects learning productivity of students' works and activities. In the field studies stated in previous chapter, the knowledge of positive associations between thermal environment parameters and survey questionnaires have been obtained, this tests was meant to serve as a self-checking tools or simulation for the participants to test or check the level of productivity at this study area, compared to the other places for study.

These tests included logical thinking and text-typing are included in Appendix B. Some simple but common students' course related tasks, especially logical thinking and text typing, were selected to represent the measures of student learning productivity. The simulation tests of mental performance are expressed in the following:

1) Logical thinking

A logical thinking is widely used to measure the mental ability and non-verbal skills. This kind of logical thinking test require subjects to have interpretation and manipulation on shapes, numbers, patterns and sequences, as many of the employer would use this system to test the candidates during recruitment process. Basically, this logical thinking test comprises of 15 questions, each of the question consists a grid of symbols. In each of the question, there is one symbol missing and the subjects would need to choose the best one from the options that fits the missing symbol. There are 12 possible answers for each of the question, but there is only one is correct. The subjects would also have to answer quickly and accurately, as there is a time-limit for 70 seconds to each of the question.

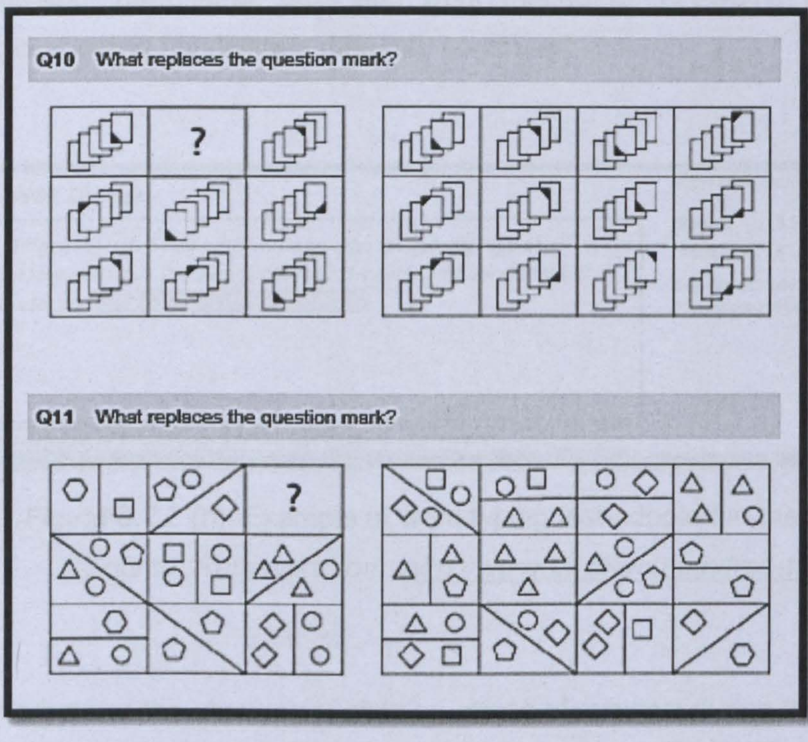

Figure 3.2.2 (a): The example of logistic thinking test adopted in the survey.
(Source: Assessment Day. Retrieved from:assessmentday.co.uk)

2) Text-typing

Each of the tasks involves dual-paradigm performance measures, e.g. text-typing involves attention and manual dexterity (O'Donnell and Eggemeier, 1986) are described. In this typing test, the subjects would have to follow the passage of words given, and re-type it out accurately and correctly. The subjects required to type it out fast, at the same time type the words by words correctly, as the words have been typed in one minute would be calculated. The results of text-typing test will be revealed in unit of wpm (words per minute). If the subject typing in a speed of 30 wpm or lower, indicating he/she is a slow typist; while a speed of 55 wpm or above revealing a fast typist; and moderate typing speed is ranged between 31 wpm to 54wpm.

The simulated self-checking test was introduced first before proceed to the set of thermal comfort questionnaire survey, which is the task to interpret their performance with respect to the current task the student subject were doing at that time. The simulated tasks has been categorized into logical thinking (memorizing, problem-solving, analysing, calculating, etc.) and work related to text-typing (writing up assignment, converting handwritten data into computer).

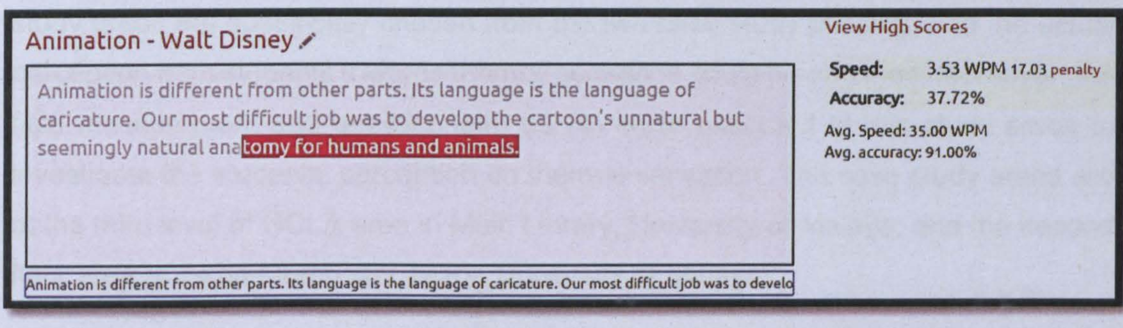

Figure 3.2.2 (b): Example of word typing test adopted in the survey.

(Source: Retrieved from: http://www.keyhero.com/free-typing-test/)

In order to mark down the changes of clothing attires of subjects during the period of the experiment, subjects needed to provide information about their clothing and were asked to record in the checklist which included in the questionnaires. A ten-point scale was used in all the subjective responses on the acceptability for thermal comfort evaluation, while the response related to perception of thermal sensation scales, were assessed following the seven-point AHSRAE 55 thermal comfort rating scale was used for both inhaled air and body thermal sensations. The subjects would have to put a tick mark on each scale according to their perception.

3.3 Qualitative Approach

3.3.1 Case Study Area Description

The libraries of University of Malaysia was developed and constructed as part of the infrastructure requirement for the area of studying, searching for resources or material, and working on the students' ongoing research, thesis or any other projects' work. The libraries within University of Malaya were chosen and included in this research according to the age. The older age of a building signifying that more problems are tends to be revealed and indoor air environment as well as thermal comfort level would be reduced. Therefore, the two oldest libraries have been chosen to study in this research, which are Main Library of University of Malaya and Za'ba Memorial Library was established in year 1959 and year 1976 respectively. For this research, study areas are specifically chosen from the two case study building, and the actual perception from students towards thermal sensation could be obtained. Moreover, the field measurement and questionnaire survey were executed at this study areas to investigate the students' perception on thermal sensation. The case study areas are at the third level of COLA area in Main Library, University of Malaya; and the second floor area of Za'ba Memorial Library, University of Malaya.

1. Case Study Area 1 – Main Library, University of Malaya

The Main Library in University of Malaya was established since year 1959, where a place that having up-to-dated collections, total of up to million titles. This library is managed by Chief Librarian who with a complement in both professional and technical support. (UM Library, 2015)

This building located at the middle of university compound, it has four floors and have been divided into areas of different functions. The location of sampling area for field measurement and questionnaire survey is at third floor Collaborative Learning Area (COLA), this area is specially designed to support students' learning and discussion. As there are provided with group meeting area, this could help the student to separate from the discussion area if they opt work quietly at study area. This creative effort was established since May 2015. (UM Library, 2015) The plan of area chosen is enclosed in Appendix A.

Figure 3.3.1(a): The COLA study area in Main Library, University of Malaya.

(Source: Field Study, 2015)

2. Case Study Area 2 – Za'ba Memorial Library, University of Malaya

The Za'ba Memorial Library in University of Malaya was established since year 1976, where a place that contains many published and unpublished materials on Malaysian, especially those materials that are rich in the scope of Malay's literature, culture and language. These materials are kept for preservation in closed stacks and occupants are allowed to do reference or reading only at designated areas. (UM Library, 2015)

This building located at Faculty of Business and Accountancy, University of Malaya, which contain of two levels which are lower ground level and ground level and the different functioning areas have been separated. The location of sampling area for field measurement and questionnaire survey is at ground floor, and the plan of chosen area is enclosed in Appendix C.

Figure 3.3.1(b): The Second Level Study Area in Za'ba Memorial Library, University of Malaya.

(Source: Field Study, 2015)

3.3.2 Observation

During the field measurement and questionnaire survey is progressing, the observations towards the condition of libraries have been undertaken simultaneously. The location and arrangement of study tables, the distribution of air diffusers, and the walling system within the study area are very important and essential to be determined, these factors are directly related to the thermal sensation response of subjects. Generally, both libraries has centralised air conditioning system and distributed evenly, as shown in Figure 3.3.2a and 3.3.2b, which allowing the temperature of working environment fix at the same temperature level.

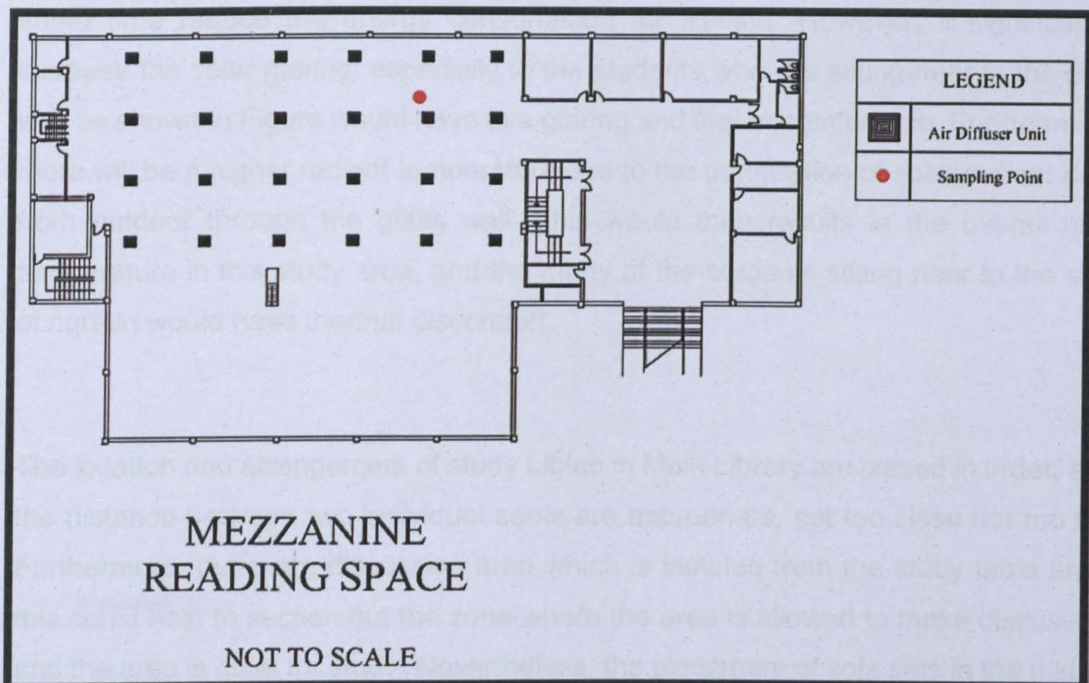

Figure 3.3.2(a): The Distribution of Air Diffuser Units in Study Area of Main Library.

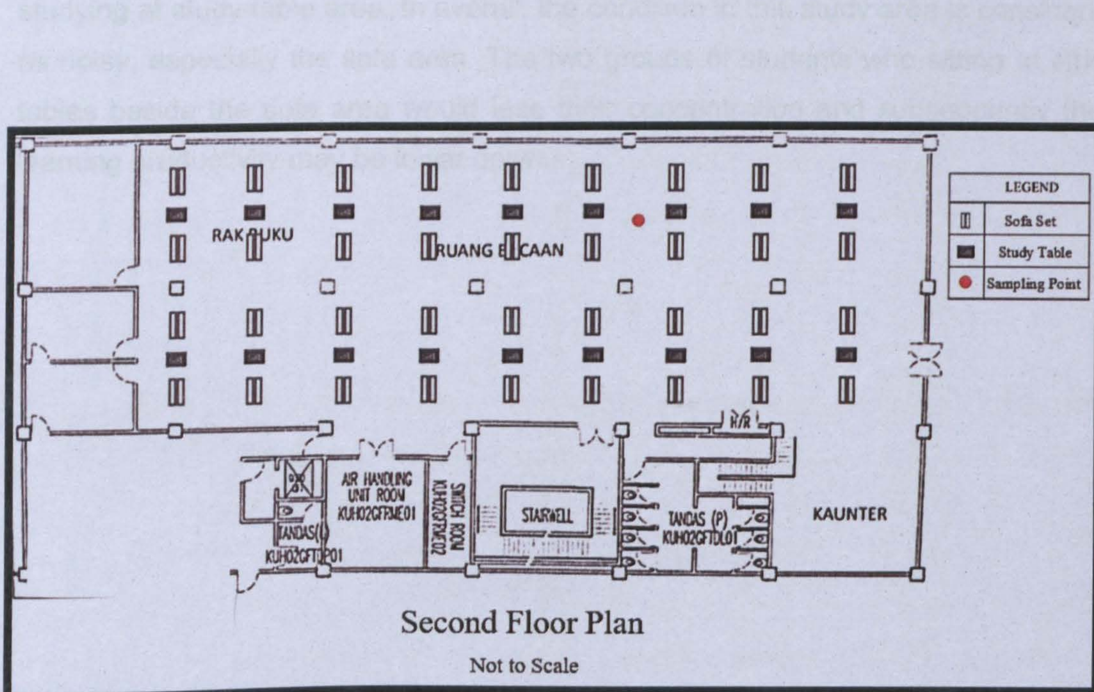

Figure 3.3.2(b): The Distribution of Air Diffuser Units in Study Area of Za'ba Memorial Library.

1. **Case Study Area 1 – Main Library, University of Malaya**

The walling system for study area in Main Library is using curtain walling system with louvres walling at external part. This aims to enhance the natural daylighting at the same time reduce the energy consumption for lighting. However, it significantly increase the solar glaring, especially to the students who are sitting near to the side wall as shown in Figure would have eye glaring and feel uncomfortable. Furthermore, there will be a higher radiant temperature due to the penetration of solar radiant heat from outdoor through the glass wall. This would then results in the overall high temperature in this study area, and the many of the students sitting near to the side of curtain would have thermal discomfort.

The location and arrangement of study tables in Main Library are placed in order, and the distance between two individual seats are appropriate, not too close nor too far. Furthermore, there are discussion area which is isolated from the study table area, this could help to section out the zone where the area is allowed to make discussion and the area is quiet for study. Nevertheless, the placement of sofa sets in the middle of group of study tables is inappropriate. The students who stayed within the sofa area are cackling, this would influence or affect the concentration of the students who are studying at study table area. In overall, the condition in this study area is considered as noisy, especially the sofa area. The two groups of students who sitting at study tables beside the sofa area would lose their concentration and subsequently their learning productivity may be lower down.

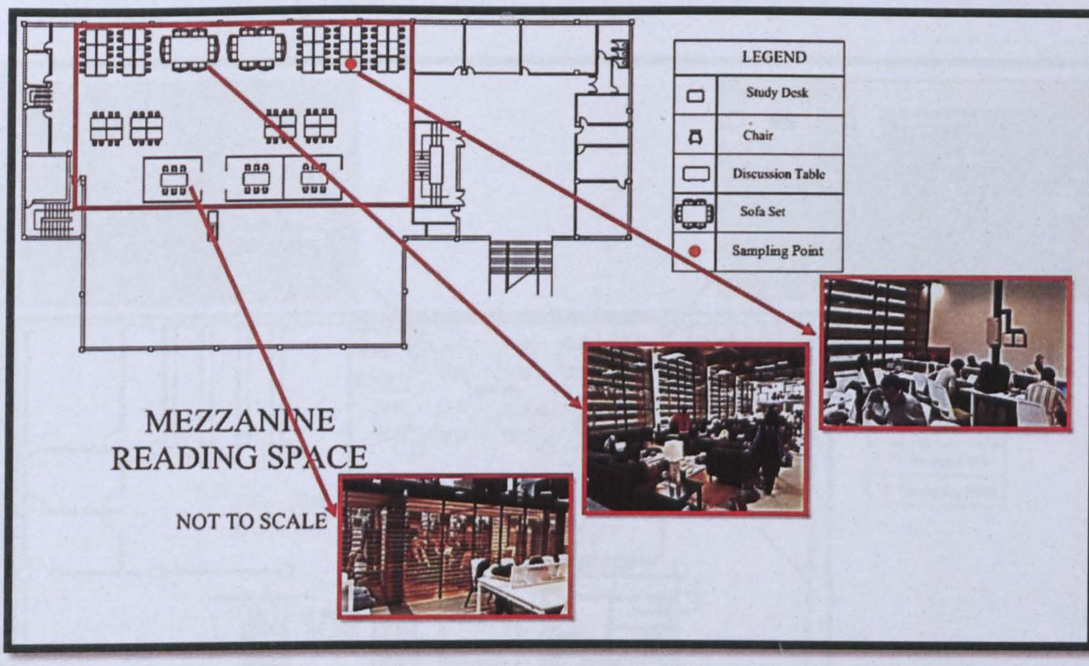

Figure 3.3.2(c): An illustrative diagram on the allocation of spaces in Main Library.

2. Case Study Area 2 – Za'ba Memorial Library, University of Malaya

The walling system for study area in Main Library is using enclosed concrete wall with a row of fixed glass panel window at top of the wall. Even though there are fixed glass panel window, there will be less amount of penetration of solar radiant heat from outdoor environment, thus a lower radiant temperature would be found. This would results in the overall low temperature in this study area, which would cause a cooler thermal sensation.

On the other hand, the location and arrangement of study tables in Main Library are placed within sufficient distance between the tables, and the distance between two individual seats are appropriately arranged, not too close nor too far. Furthermore, there are sofa area in the middle of group of study tables, this is for the students to take a rest whenever they are getting too tensed. Generally, the students occupied within this study area were remain quiet and silent, so the students could remain committed to concentration on their learning activities. Hence, the productivity may be enhanced by maintaining their concentration, regardless of the other environment factors.

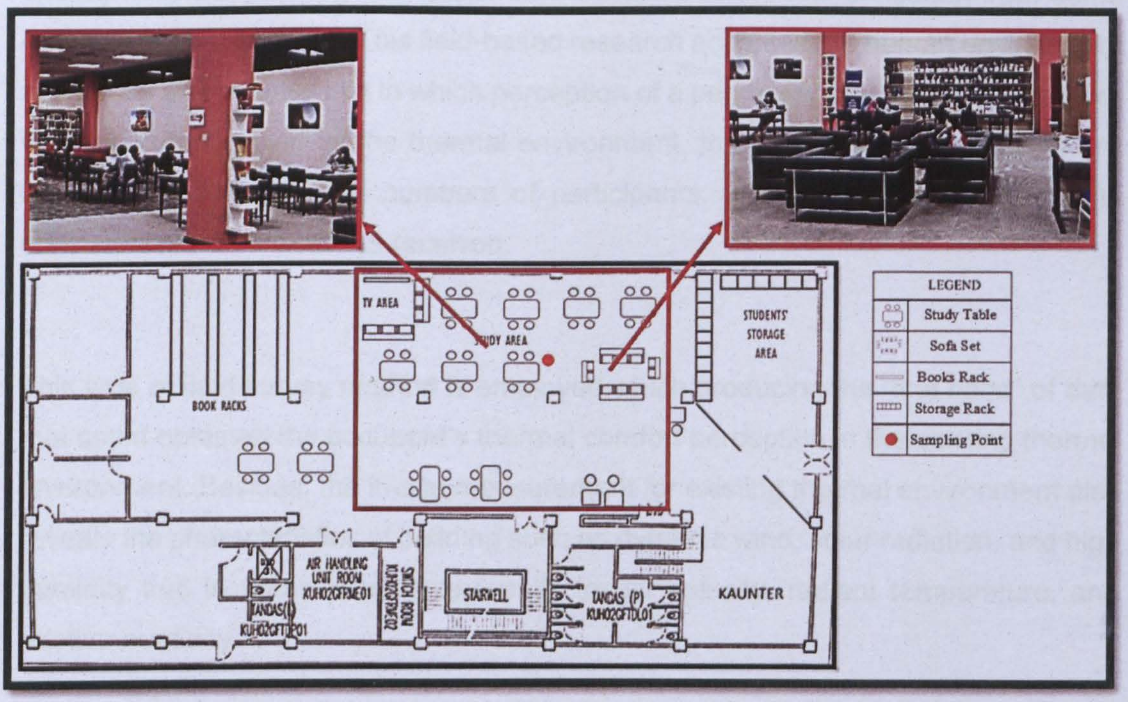

Figure 3.3.2(d): An illustrative diagram on the allocation of spaces in Za'ba Memorial Library.

3.4 Data Analysis

3.4.1 Quantitative Approach

Quantitative approach analysis were subjected to analyse data from physical measurement and surveys. Within each experiment, analyse of variance and patterns of air temperature, relative humidity, mean radiant temperature and air velocities parameters were required to ensure no major conflicts between the perceived responses.

The methodology allows an independent environmental variable to be operated directly whilst separating with dependent variables of thermal sensation from some other external influences. This field-based research accepted the human environment system as an essential unit in which perception of a personnel and their sensation are very much influenced by the thermal environment. In addition, this field studies are usually based on a large numbers of participants, and thus further improved its consistencies on the results received.

This type of field survey method is employed which producing the "first hand" of data that could obtained the occupant's thermal comfort perception in the existing thermal environment. Besides, the in-situ measurement for existing thermal environment also reveals the characteristics of building such as dynamic wind, solar radiation, and high humidity that in order to achieve results for air velocity, radiant temperature, and relative humidity.

In order to explore the relation between these variables to presume the possible pathways or mechanisms introduced upon establishing the effects of the experimental conditions on various human responses and performance variables. Statistical Package for Social Science (SPSS) using statistical analysing program with data management and documentation system, were applied to reshape file and derive the data according to observed relationships in the logical theoretical construction.

3.4.2 Qualitative Approach

The details and observations obtained from case study area, would be included during the analysis of those date gathered. The location and arrangement of study tables, the distribution of air diffusers, and also the walling system would not be ignored throughout the data analysis process. The existed condition or situation of each of the libraries found from the observation, should be considered as the effect or reason for the results of thermal environment or thermal sensation.

3.4.3 Overall Analysis

The factors of affecting overall thermal sensation would be deduced from association of the perceived responses with the measured thermal environmental parameters. The relationship of each and every of the parameters or variables would affecting the thermal sensation will be explored. These parameters will be analysed using SPSS statistic system, and the most significant variables would be investigated.

Following with that, the learning productivity would be further analysed whether it is having great effect or correlated with the overall thermal sensation. Thermal sensation will be the core dependant variable throughout this research whether on the thermal environmental parameters, perceived responses aspect or both of these.

CHAPTER 4.0

RESULTS AND ANALYSIS

4.1 Framework of Data Analysis

A systematic analytical structure is applied after all the data were collected and gathered from both field measurement and questionnaire survey. Basically, there are two methods of analysis being adopted in this research, which is Quantitative and Qualitative type of approaches. Quantitative method is used along with appropriate statistical tools in interpreting and evaluating the relationship having between environment measurement data and human's perception scales. The results obtained are then involved in constructing reliable statistics which are very much depend on the descriptive comparison of data. In addition, by applying Qualitative Method would generates better effect in producing the descriptive comparison among the data.

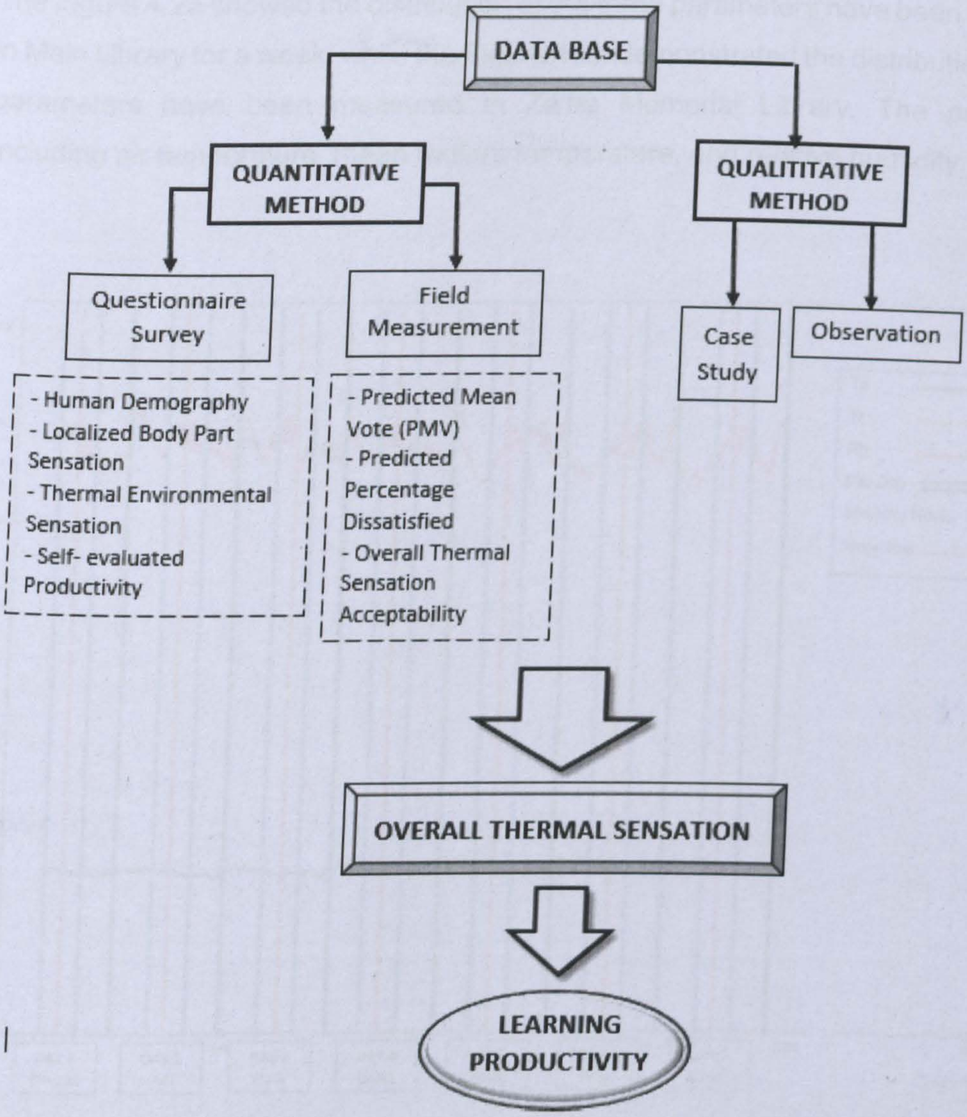

Figure 4.1: Systematic Analytical Framework Structure for Data Analysis.

4.2 Thermal Environmental Parameters

This study measures the libraries is to present the different environment parameters or climatic factors such as air temperature, mean radiant temperature, relative humidity, and air velocity. The results shown were the data analysed from the gathered data of environmental parameters every day for one week in each of the library.

The Figure 4.2a showed the distribution of the three parameters have been measured in Main Library for a week, while the Figure 4.2b demonstrated the distribution of three parameters have been measured in Za'ba Memorial Library. The parameters including air temperature, mean radiant temperature, and relative humidity.

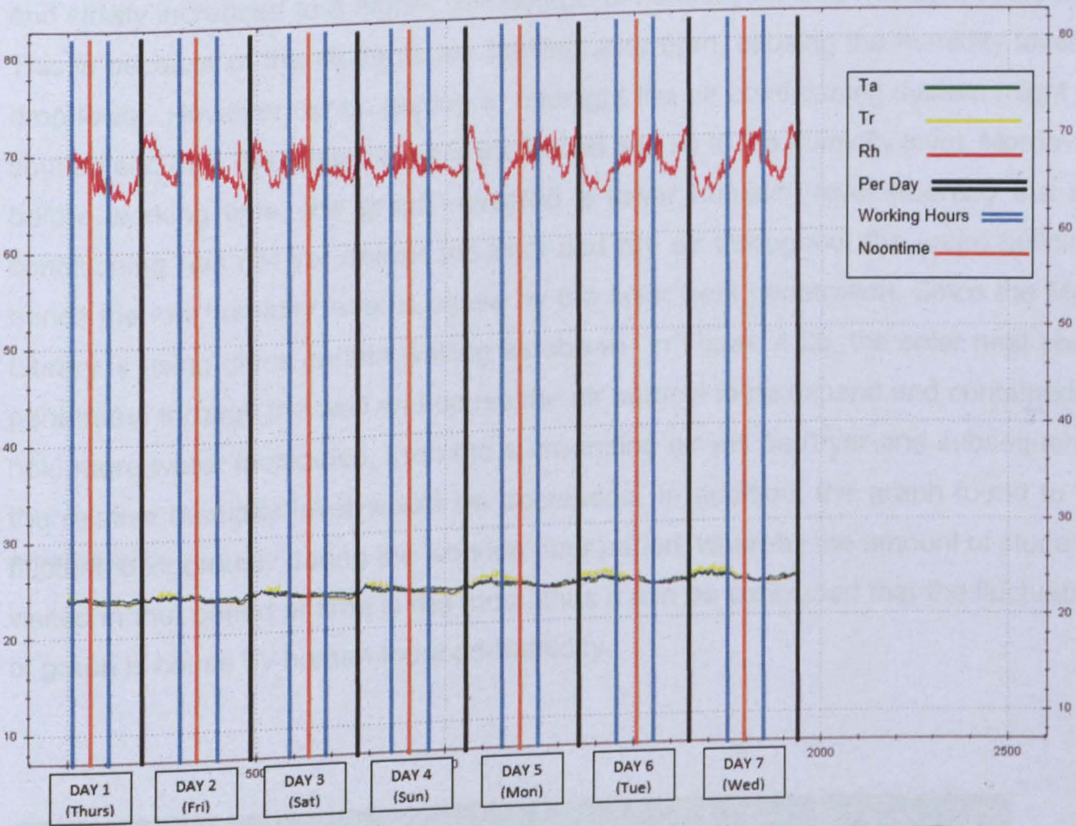

Figure 4.2(a): Distribution of Three Measured Environmental Parameters in Main Library.

The pattern of air temperature, radiant temperature and relative humidity having in Main Library (Figure 4.2a) demonstrated a series or sequences of identical pattern of graph throughout the field measurement period. For air and radiant temperature, it showed to be lower temperature at night time every day after working hour period, the graph have fall in temperature after 6pm every day. This is because of lesser students occupied in that study area, students would choose to go back their house or room after 6pm, due to safety reasons. Besides, the air and radiant temperature found to be at higher temperature during starting of working period and even higher before start working. The reason believe to be the main library is stop operate every day from midnight 12am until the morning 9am, thus this period would be supplied with lesser air or higher temperature of air-conditioning, compared to occupying period.

On the other hand, the relative humidity has revealed a lower humidity level after 6pm and slowly increased to a higher percentage of humidity level at midnight every day. This is because of the students are leaving after 6pm, causing the humidity level to drop lower. However, when getting to midnight the air conditioning system might be shut off and thus the temperature is increased and so to the humidity level. Moreover, before working time, the graph revealed a lower humidity level whereby the air-conditioning has not yet deliver the cool and dry air throughout the entire building, hence the low humidity level is cause by the solar heat penetration. Since the Main Library is using glass curtain walling as shown in Figure 4.2b, the solar heat could penetrated through the wall and cause the air particle to be expand and contained or hold more water molecules, then the surrounding air will be dryer and subsequently the relative humidity level would be decreased. In addition, the graph found to be fluctuated vigorously during the working hour period, whereby the amount of students visited in that period of time is the most, thus it can be concluded that the fluctuation of graph is cause by human induced-humidity.

Figure 4.2(b): The curtain walling system used in Main Library.

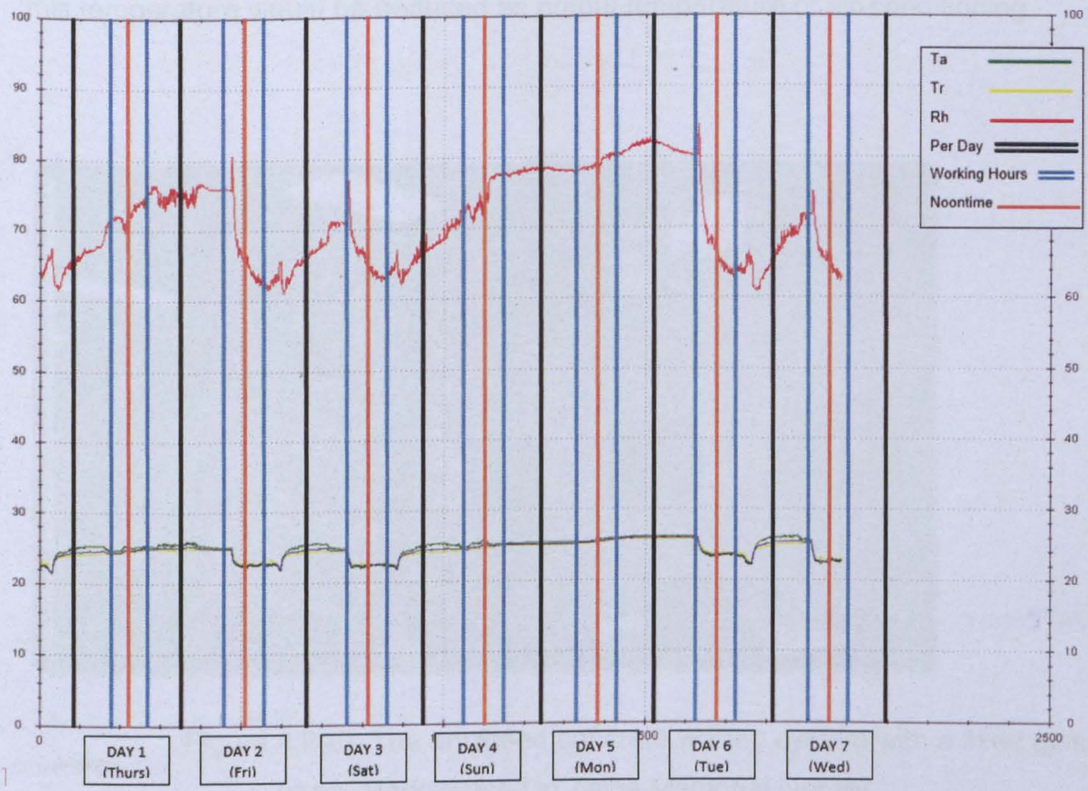

Figure 4.2(c): Distribution of Three Measured Environmental Parameters in Za'ba Memorial Library.

The pattern of air temperature, radiant temperature and relative humidity having in Za'ba Memorial Library (Figure 4.2c) demonstrated non-identical sequence or pattern of graph and greatly fluctuated throughout the field measurement period. Generally, on Tuesday, Wednesday, Friday, and Saturday, the noontime period have revealed relatively low air and radiant temperature reading. This may due to most of the students would choose to visit to Za'ba Library on these days during lunch time. The large amount of occupants would definitely raise the air temperature, however the radiant temperature will lower down the temperature to counteract with the increased air temperature. Since this building is using enclosed concrete walling system with a fixed glass panel window on top of the wall as shown in Figure 4.2.d, the radiant temperature would move in the cool air to counteract with warm air. As the fixed glass panel window is located at the top part of wall, the warm air would be transfer out, and no warm air will be flow in and downwards. Hence, the cool air will keep regulated in, and cause the overall temperature to be lower. Furthermore, the air and radiant temperature is maintained at same level all the time every day, and students are less likely to visit at that time of period (library operation time is form 8.00am-5.30pm), thus this temperature would be deduced as output temperature of air-conditioning.

Figure 4.2(d): The enclosed concrete walling system with a fixed glass panel window used in Za'ba Memorial Library.

On the other hand, the relative humidity has demonstrated great fluctuation throughout the field measurement period. As the lower temperature would bring a lower humidity level, thus during the Tuesday, Wednesday, Friday and Saturday noontime, the humidity level are all found to be reduced at that point.

From the Figure 4.2e and 4.2f, the air and radiant temperature for both libraries are found to lies within the range as provided in all standards. However, the relative humidity level for both libraries are out of range, especially to the ASHRAE 55 and Environmental Guidelines for Library and Archives which should be lower than 60% and 50% respectively. Furthermore, the relative humidity level in Main Library is just as near as in compliance with ISO 7730 standard, whereby there are few points have fall beyond the maximum 70% as stated in ISO 7730. On the other hand, the relative humidity level in Za'ba Memorial Library can said to be not in compliance with ISO 7730, as the majority of the readings are fall out of the maximum borderline.

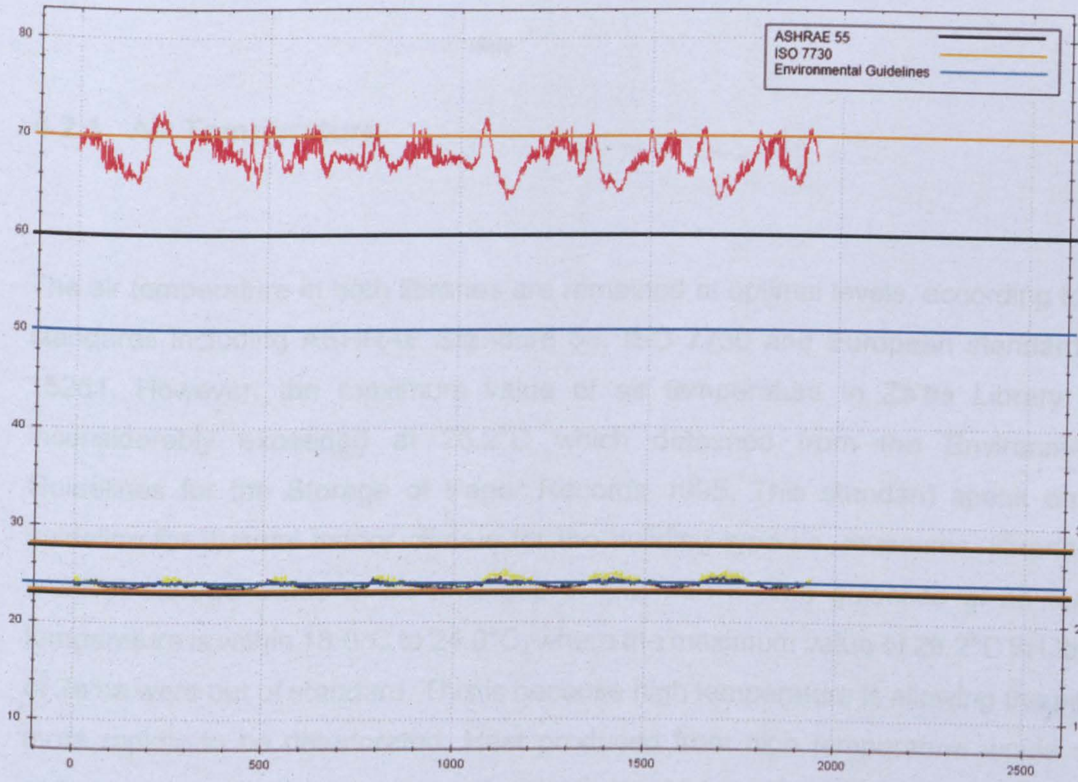

Figure 4.2(e): The comparison of the environment data in Main Library with those standards and guidelines.

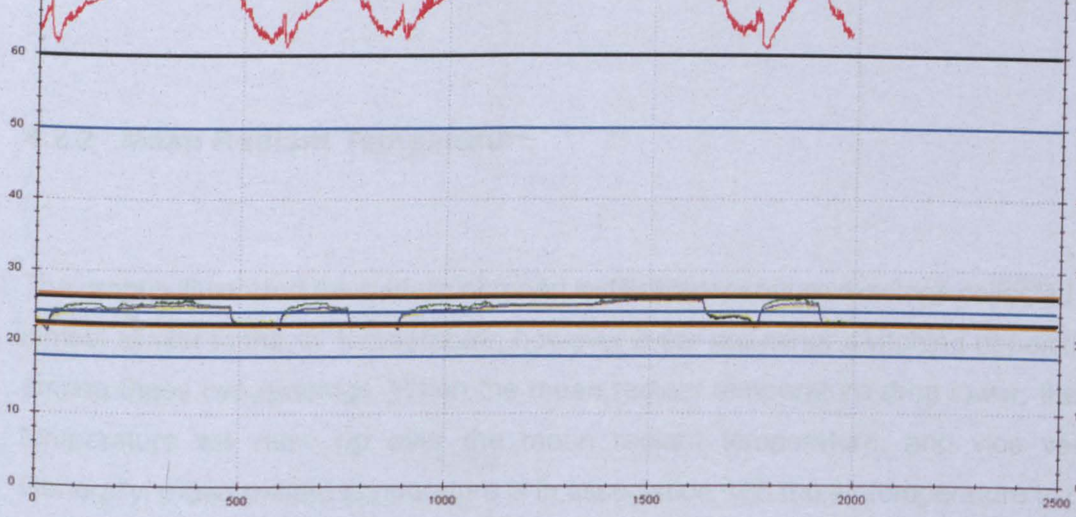

Figure 4.2(f): The comparison of the environment data in Za'ba Memorial Library with those standards and guidelines.

4.2.1 Air Temperature

The air temperature in both libraries are remained at optimal levels, according to the standards including ASHRAE Standard 55, ISO 7730 and European standard EN 15251. However, the maximum value of air temperature in Za'ba Library was inconsiderably exceeded at 26.2°C which detached from the Environmental Guidelines for the Storage of Paper Records 1995. This standard speak on the guideline for thermal indoor climate for the building type i.e. museums, libraries or archival storage areas to be arranged in line with it. The guideline given for air temperature is within 18.0°C to 24.0°C, where the maximum value of 26.2°C in Library of Za'ba were out of standard. This is because high temperature is allowing the paper more rapidly to be deteriorated. Heat produced from high temperature would also causes water, plasticizers, and solvents to be driven off easily, which would then strengthen the pollutants to be reacted with materials and increase the microbiological activity by changing the acidity. Furthermore, the paper materials also will alternately contract and expand due to fluctuations in temperature that were out of the prescribed range of standard, consequently will lead to cracking of materials. As observed from the Graph 1 and Graph 2, the air temperature readings in Main Library have only small and minor fluctuation, in contrast with the Za'ba Library found to have occasionally great fluctuation of air temperature readings.

4.2.2 Mean Radiant Temperature

The graphs illustrated the pattern of mean radiant temperature readings collected are almost similar to the air temperature, however there are minor switching of positions among these two readings. When the mean radiant temperature drop lower, the air temperature will raise up over the mean radiant temperature, and vice versa. Generally, mean radiant temperature is in association with the air temperature to give impact on the thermal comfort, while it behaves independently to the air temperature. When there is a passive solar gain produces an increase in thermal radiation, the radiant heat gain will not just balanced out with the cold surface within an area, but will also release to cooler air temperature to achieve thermal comfort. In another way round, the air temperature have to increase if the mean radiant temperature drops due to lack of radiant solar heat gain. The lower the mean radiant value, the higher the corresponding air temperature required to achieve thermally stable of the comfort zone.

4.2.3 Relative Humidity

From the Table 2 with comparing to the standards Table 3, the average value of relative humidity parameters were located at very high range and even exceed the ASHRAE Standard 55 and also the Environmental Control for Museums, Libraries and Archival Storage Areas 2004. The mean and maximum value of relative humidity in Main Library were 67.83% and 72.6% respectively, whereas the readings in Za'ba Library were 71.34% and 87.6% accordingly. There might be a difference of 3.3% by taking into the consideration of the existence of large group of occupants, whereby the mass in relative humidity is mostly influenced by people. A normal range of relative humidity will help in dissipation the metabolic heat existed between the skin and clothing layers without uncomfortable effect. Nevertheless, a high range of relative humidity would lead to bio-deterioration in all biologically, physically and chemically modes. Paper and other materials used in records might absorb the moisture and the metal corrosion, bacterial growth, splitting and warping to be occurred. Besides, a too low relative humidity would cause material to shrink and dry.

4.2.4 Air Velocities

From the Table 4.2.5, the readings of air velocity recorded in both libraries are disclosed a below standard range of air velocities. In Main Library, even the maximum value of air velocity showed a speed of 0.23 m/s, but there are many more while the main library has zero air flow or air velocity which then contributed to an average of 0.03 m/s of air velocity. In ASHRAE 55, the minimum requirement for air velocity is at least 0.15 m/s, hence the air velocity in main library can be concluded to be out of range. This might bring out a sequence of air flow-related syndrome, such as difficult to breathe and headache. In Za'ba library, the similar condition has been found, there are quite a lot of moment were showing zero air velocity, although the maximum speed was up to 0.2 m/s, but it was rare case and sum up a 0.01 of mean air velocity. When air temperature is produced by the heating or cooling system, the movement of air is important to bring or balance out the overall temperature in the entire area by transmission of air. If the air velocity didn't existed or not effective enough to transfer the temperature around, which means probably more mechanical systems i.e. fans or forced air system, will be needed in inducing more air flow. (Mid-Atlantic Masonry Heat, 2011)

4.2.5 Measured PMV and PPD

When all the parameters that required to be taken account to Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) have been recorded, the PMV and PPD can be calculated. By referring to the thermal scale standard that originally developed by Fanger which later on being adopted as 7-point scale in ASHRAE standard, it stated the scale executed between the range cold (-3) to hot (+3). Moreover, as the PMV shifts further from neutral (0), the PPD will increases in accordance to ASHRAE 55. Therefore, the recommended range of acceptable thermal comfort PPD is less than 10% occupants dissatisfied for that particular space or area. Meanwhile, the suggested acceptable PMV range for an interior space in ASHRAE 55 is between -0.5 to +0.5. From the results of measurement achieved in Table 4.2.5, the PMV and PPD for main library is 0.11 and 5.3% respectively, while the PMV and PPD for Za'ba library is 0.34 and 7.4% accordingly. In other words to say, both of the libraries have been ascertained as situated within the standard range, the students will be thermally satisfied with the indoor environment.

Table 4.2.5: Evaluation of Results of Environment Parameters with Respect to Libraries

Libraries		Air Temp.	Mean Radiant Temp.	Relative Humidity	Air Velocity	PMV	PPD (%)
Main Library	Mean	23.95	23.92	67.83	0.03	0.11	5.3
	Minimum	23.2	23	63.4	0	-	-
	Maximum	24.6	25.6	72.6	0.23	-	-
	Standard Deviation	0.2087	0.5221	1.7047	0.048	-	-
Za'ba Library	Mean	24.72	24.34	71.34	0.01	0.34	7.4
	Minimum	21.3	21.5	60.9	0	-	-
	Maximum	26.2	25.8	84.6	0.2	-	-
	Standard Deviation	1.2429	0.9863	6.2349	0.0217	-	-

4.3 Human Factors

There are total of 188 participants responded from Main Library and Za'ba Memorial Library, with total of 106 and 82 participants from each of the library respectively. The survey was laid out as cross sectional data collection which the once-off sampling from the participants were carried out. Furthermore, the data collection of questionnaire survey were divided into two sessions of the day, that stand in to indicate the better distribution of the actual indoor thermal environment and conditions in an all-day basis. Due to the limited access to the Za'ba Memorial Library, the surveys were not carried on during night time (17.00 – 09.00am) for both libraries to enhance the consistencies. The data sampling distribution is presented in Table 4.3.

Table 4.3: Cross-tabulation between libraries and sessions.

Library		Session		Total
		Morning	Afternoon	
Main Library	Count	55	51	106
	% within Library	51.9%	48.1%	100.0%
Za'ba Library	Count	34	48	82
	% within Library	41.5%	58.5%	100.0%
Total	Count	89	99	188
	% within Library	47.3%	52.7%	100.0%

4.3.1 Gender and Age Distribution

There are total number of 75 (39.9%) and 113 (60.1%) responses were gathered from male and female participants accordingly which shown in Table 4.3.1(a), the gender distribution of the total data sample within library. Obviously, the results reported a larger number of female participants for both libraries compared to males. Female participants contributed 58.5% in Main Library and 62.2% in Za'ba Library, while percentage of male have accounted only for 41.5% and 37.8% respectively.

Table 4.3.1(a): Cross-tabulation between libraries and sessions.

Library		Gender		Total
		Male	Female	
Main Library	Count	44	62	106
	% within Library	41.5%	58.5%	100.0%
Za'ba Library	Count	31	51	82
	% within Library	37.8%	62.2%	100.0%
Total	Count	75	113	188
	% within Library	39.9%	60.1%	100.0%

On the other hand, Table 4.3.1(b) shows the distribution of age of the data sample collected within the library. The biggest percentage of age group found from participants in Main Library were 64.2% represented by young adult (21~30 years old) and the smallest percentage of age group was between 31~40 years old which contributed only 3.8%. The age group of below 20 years old was accounted half of the largest age group for 32.1%. Similarly, the largest percentage of age group in Za'ba Library was fell under young adult group as well (21~30 years old) and the least percentage of 1% was found to be in age group of 31~40 years old. The below 20 years old was in moderate scale of percentage (37.8%). The range of age for more than 40 years old has no data been collected, as in the occupants within the libraries were almost undergraduate and postgraduate students. From the above comparisons made, the percentage range of age groups for both libraries didn't varied much, can be said as almost similar range of age group of students who have visited to the libraries.

Table 4.3.1(b): Cross-tabulation of Age Group with Respect to Libraries.

Library	Age Group (years old)			Total	Mean of Age (years old)
	< 20	21 ~ 30	31 ~ 40		
Main Library	34 32.1%	68 64.2%	4 3.8%	106 100.0%	22.71
Za'ba Library	31 37.8%	50 61.0%	1 1.2%	82 100.0%	21.39
Total	65 34.6%	118 62.8%	5 2.7%	188 100.0%	22.13

4.3.2 BMI Range

From the data gathered for both libraries, the average of height and weight of participants are fell within the range of Standard Body Mass Index for Asians (Wang et. al, 1994) and the suggested BMI range for ideal weight (Jones, 1999). Generally, the difference of average BMI readings between the gender group have no remarkably distinction. The average BMI reading for male and female group in Main

Library were pertained within the same category of 21kg/m², while the male group in Za'ba Library has a slightly higher average BMI reading than the female group. The data and standard number range of BMI accordingly to the gender are stated in the Table 4.3.2. There is an illustrative example of average BMI group of people from the results achieved shown in Figure 4.3.2.

Table 4.3.2 : Cross-tabulation of Average BMI with Respect to Gender and Libraries

Parameters	Main Library (n=106)		Za'ba Library (n=82)	
	Male	Female	Male	Female
Height (m)	1.71	1.62	1.71	1.61
Weight (kg)	62	56	63	52
BMI (kg/m²)	21.03	21.12	21.36	20.16
Standard BMI for Asian (kg/m²)	23.3	22.0	23.3	22.0
Range of Ideal BMI (kg/m²)	20.7~26.4	19.1~25.8	20.7~26.4	19.1~25.8

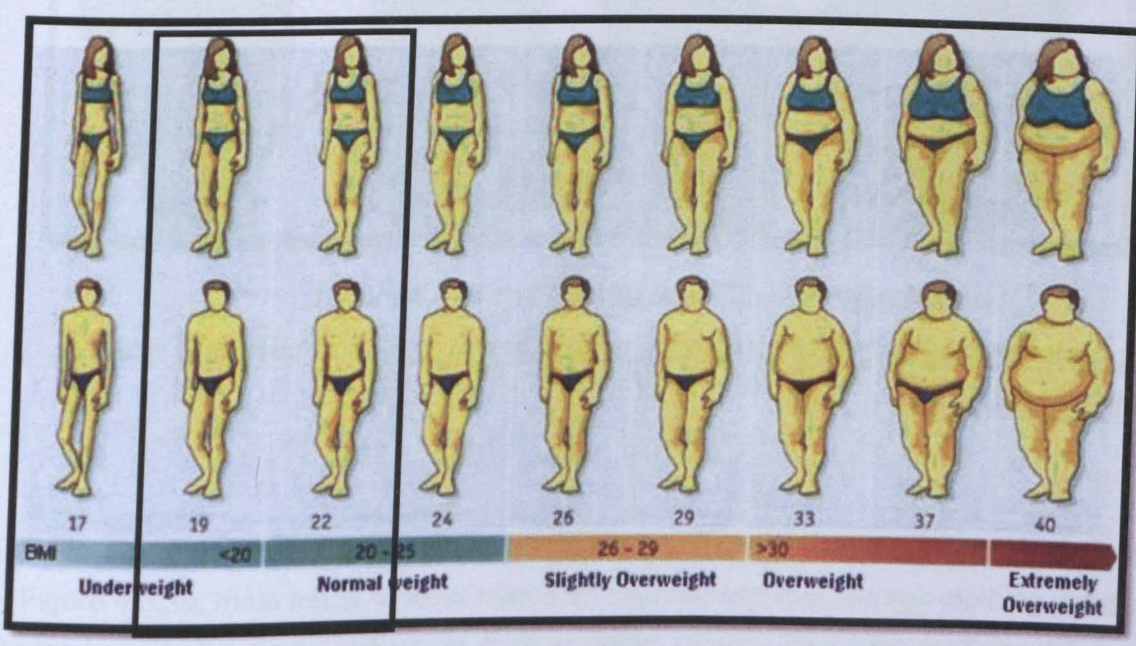

Figure 4.3.2: An illustrative example of average BMI group of people.

(Source: Reddit, 2015

4.3.3 Clothing Value

During the period of conducting survey, the participants were required to fill in the clothing attire that they are wearing, which the clothing value sheet was included in the questionnaire set. The analysis results depicted the mean clothing value of female group is higher than male in both libraries regardless of the geographical distribution. This might due to the religious clothing existed in Malaysia, especially the Muslim female. In the admonishes of The Quran, a Muslim female is required to dress modestly and covering whole body except face and hands as a symbol of modesty and privacy. (Fadwa, 1999). In Figure 4.3.3a, the example of clothing type for Muslim female.

Figure 4.3.3(a): Clothing example of Muslim female.

(Source: Retrieved from: http://www.triviacell.com/2014/05/about-91-percent-of-us-lie-regularly.html .)

As in many occasions been observed during the survey and the results shown in Figure 4.3.3b, male tends to wear minimum clothing and the average clothing values also revealed a lower values of 0.59 in Main Library and 0.65 in Za'ba Library compared to female. On the other hand, female contributed 0.66 of clothing value in both libraries which is higher than male. This would raised up a question that why there is a higher average clothing value of male in Za'ba Library in contrast to Main Library, it might due to the higher air temperature. In Figure 4.3.3c, there are the examples of clothing attire which closely indicated the average clothing value in library.

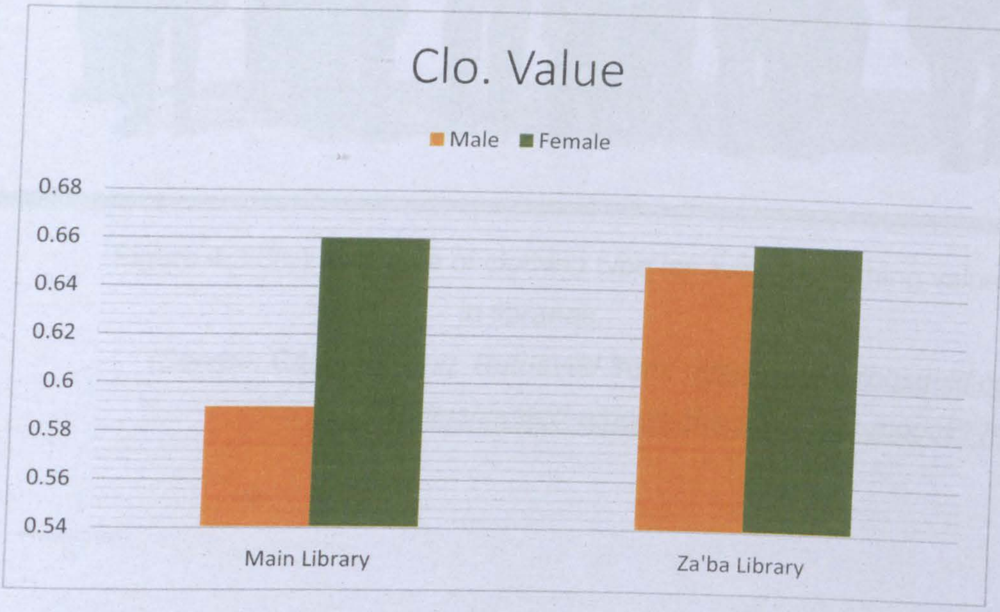

Figure 4.3.3(b): Distribution of Clothing Value against Gender and Libraries.

Table 4.3.3: Cross-tabulation of Results for Clothing Values with Respect to Gender.

Gender	Mean	N	Std. Deviation
Male	0.6116	75	0.14832
Female	0.6602	113	0.12714
Total	0.6408	188	0.13768

Figure 4.3.3(c): Example of clothing type for average clothing value found in libraries.

(Source: Casual Sitting. Retrieved from: http://www.turbosquid.com/3d-models/seated-african-characters-3d-model/774901 .)

4.4 Perceived Responses to Thermal Environment

The first task in analyzing the data is to differentiate whether all the values of data or parameters are in parametric or non-parametric statistic form. The statistic of Skewness and Kurtosis of the data shown to be within the value of $-2 \leq x \leq 2$ would indicate the sample data to be parametric, or vice versa. The parametric statistic is normally distributed, that would have homogeneity of variance which make the statistics to be continuous. A normal distribution of a parametric statistic contains only 68.26% of its data that have not vary much from the standard deviation value of -1 to 1 from the mean calculated.

The data gathered from the questionnaire were group into four (4) parameters to define the overall thermal sensation, which included:

I. Demography Information : Case Study Library, Gender, Sufficient Sleeping Hours, Meal Taken, Work Nature, Working Alone, BMI Group, Age Group and Clothing Value Group

II. Localised Sensation Parameters: Body Parts of A to K

III. Thermal Environmental Sensation Parameters: Thermal Comfort Level, Level of Coldness, Level of Humidity, Level of Air Freshness, Level of Air Flow, and Sweat Rate

IV. Self-Evaluated Productivity Parameters: Level of Sleepiness, Difficulty to Concentrate, Effort Paid to Complete Work, and Productivity of Work.

Concluded from the Table 4.4(a), Table 4.4(b), Table 4.4(c), Table 4.4(d) and Table 4.4€, majority of the standard deviation values were fell within the range of -1 to 1. For the skewness and kurtosis values for all four parameters were also fitted within the range, except for the average of meal taken and the level of draftiness, these two parameters would be excluded in the parametric type of data analysis.

Table 4.4(a): Statistics of Skewness and Kurtosis of Demography Parameters.

	Library	Gender	Suf. Sleep Hrs	Meal Taken	Work Nature	Work Alone	BMI Group	Age Group	Clo. Group
N	188	188	188	188	188	188	188	188	188
Mean	1.44	1.60	1.37	1.04	1.61	1.50	1.96	2.14	2.15
Std. Deviation	0.497	0.491	0.483	0.202	0.489	0.501	0.472	0.390	0.596
Skewness	0.260	-0.416	0.556	4.569	-0.462	0.000	-0.137	1.253	-0.063
Kurtosis	-1.954	-1.847	-1.709	19.080	-1.806	-2.022	1.523	1.997	-0.303

Table 4.4(b): Statistics of Skewness and Kurtosis of Localised Sensation Parameters.

Body Parts	A	B	C	D	E	F	G	H	I	J	K
N	188	188	188	188	188	188	188	188	188	188	188
Mean	4.65	4.61	4.72	4.95	5.02	5.27	5.48	5.93	4.78	5.21	5.80
Std. Deviation	1.385	1.334	1.432	1.293	1.342	1.397	1.435	1.827	1.349	1.205	2.043
Skewness	-.350	-.338	-.132	.285	-.003	.015	.136	.162	.074	.046	-.077
Kurtosis	.323	.311	.585	.949	.503	.363	.139	-.516	.005	.255	-.626

Table 4.4(c): Statistics of Skewness and Kurtosis of Environmental Sensation Parameters.

	TC Level	Level of Air Coldness	Level of Air Humidity	Level of Air Freshness	Level of Air Flow	Sweat Rate
N	188	188	188	188	188	188
Mean	4.65	5.48	5.36	5.16	4.99	5.84
Std. Deviation	1.682	1.306	1.140	1.849	1.416	2.010
Skewness	-.531	.469	.316	-.083	-.653	.245
Kurtosis	.693	.481	.647	.278	2.169	.117

Table 4.4(d): Statistics of Skewness and Kurtosis of Self-Evaluated Productivity Parameters.

	Level of Sleepiness	Difficulty to Concentrate	Effort Paid to Complete Task	Productivity of Work
N	188	188	188	188
Mean	5.05	4.88	5.62	5.71
Std. Deviation	1.961	1.972	1.538	1.573
Skewness	-0.247	-0.440	-.076	0.219
Kurtosis	0.716	0.851	0.371	0.005

Table 4.4(e): Statistics of Skewness and Kurtosis of Overall Thermal Sensation

	Overall Thermal Sensation
N	188
Mean	-0.23
Std. Deviation	.951
Skewness	-0.130
Kurtosis	-.063

Since the data analysis is using parametric statistic method, the bivariate correlation between existed those parameters and data have to be identified to proceed further steps. The Pearson's bivariate correlation tables, Table 4.4(f), Table 4.4(g), Table 4.4(h) and Table 4.4(i) were included in the Appendix D. By referring to the Pearson's coefficient and significance value, some parameters found to be correlated amongst each other. There were a lot of data that found to be significant to the others, however Pearson's coefficient is more able to indicate the real linear correlation between the two parameters which measure the extent of linear dependence within the related parameters.

The parameters that were discovered be in significance with the overall thermal sensation comprises of gender, clothing value, working alone, body localized sensation of part B, C, E , F, G, H, J, K, thermal comfort level, level of coldness, level of humidity, level of air freshness, effort paid to work, and productivity of work. First, the gender is a relevant parameters to the overall thermal sensation was because of the localized sensation and environmental sensation factors, refer to Table 4.4(h). This situation occurred could be due to females have generally higher temperature at body parts of front of neck, back of neck, chest, back and upper arms areas which corresponded to Chapter 2.3.1 mentioned earlier. These areas having high temperature would cause the body condition exposed to stuffy and still air. Secondly, clothing value would said to be significant to overall thermal sensation that was because of a slightly higher average clothing value of the participants in libraries if compared to the standard clothing level. The average clothing level of male and female were 0.61 and 0.66 respectively in Table 4.3.3, which are higher than 0.55 of standard clothing level, hence this might cause an effect on overall thermal sensation.

Next, working alone would influence on the overall thermal sensation. From table 4.4(g), the reason why on the effect of working alone could be deduced that a person who working alone is lack of movement. A very low amount of air movement will accumulate surrounding heat and humidity consequently easy to feel stuffy (Kelly, 2013) .

On the other hand, the overall thermal sensation was also correlated to the other three factors, i.e. localized sensation, environmental sensation and self-evaluated productivity factors. These factors have been grouped by the relevant parameters and resulted negatively significances to the overall thermal sensation. To examine on the localized sensation, there are some parameters found to be significant to the overall thermal sensation that consist of body part B, C, E, F, G, H, J and K. From these parameters, the body parts B, C, E, F, G and J found to be having mutual interrelated amongst each other, meaning that the part of front of neck, back of neck, back, upper arms, lower arms and calf areas influencing each other and also the overall thermal sensation. At the same time, the body part B has showed a negatively direct effect on the overall thermal sensation as well. In addition, the body part H and K were discovered to react closely with the body part F, G and J. Since the lower arms and upper arms were connected to the hands part, while calves were closed to feet areas, and hence there built the significance to each other that correlated to overall thermal sensation. Besides, the body part of C, F, G and H have also influenced on overall thermal sensation by having common positive effect with the level of coldness which have also contributed positive influence on the thermal comfort level. The thermal comfort level played important role in negatively correlating with the overall thermal sensation, due to the level of coldness is exerted great positive effect onto it. Moreover, the level of dryness has been indicated to have direct positive effect on the overall thermal sensation, which induced a warmer ambient and stuffy air that would make people feel uncomfortable towards the thermal environment.

Although there are a lot of parameters or factors having effect to the overall thermal sensation, however the most relevant data left only six parameters after the multiple linear regression method had been applied. The highest correlation from localized sensation body part K, the level of air flow, level of coldness, body part E and working alone affected the least, referring to the Table 4.4(g). In the column labelled R is showing the coefficient of multiple correlation between the predictors and outcome, and the correlation between the body factor K, the level of air draftiness, level of coldness, body part E and working alone with the overall thermal sensation is 0.63. Next, the R^2 is a weightage of the consistency of the predictors accounted to the outcome. The first model showed a value of 0.172 deducing that body part K recorded for 17.2% of the changes in overall thermal sensation and therefore the increase of R^2 in the following rows to display the changes or variation after any parameters enter into the model. The sixth (6th) model demonstrated an increase of 22.5% from the first model. Beside that, the adjusted R^2 presented to illustrate how well the value of model close to the value of R^2. In this case, the final (6th) model has a different of 2%, and this decrease of value deriving the outcome of model is accounting 2.0% less in variance. In the last column, the model found that a 2.016 value of Durbin-Watson statistic calculated which present a zero serial correlation among the residuals. This statistic assisted in assuming the independent errors to be tenable, the better the model is it closer to value 2 stated in general rule of thumb. (Field, 2009)

Table 4.4(j): Evaluation of Model Summary of Multiple Linear Regression

Model	R	R Square (R^2)	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.415[a]	.172	.168	.868	.172	38.645	1	186	.000	
2	.525[b]	.275	.267	.814	.103	26.339	1	185	.000	
3	.578[c]	.334	.323	.783	.059	16.214	1	184	.000	
4	.597[d]	.356	.342	.771	.022	6.354	1	183	.013	
5	.610[e]	.373	.355	.764	.016	4.732	1	182	.031	
6	.630[f]	.397	.377	.750	.025	7.460	1	181	.007	2.016

a. Predictors: (Constant), K

b. Predictors: (Constant), K, Level of Air Flow

c. Predictors: (Constant), K, Level of Air Flow, Level of Coldness

d. Predictors: (Constant), K, Level of Air Flow, Level of Coldness,

e. Predictors: (Constant), K, Level of Air Flow, Level of Coldness, E

f. Predictors: (Constant), K, Level of Air Flow, Level of Coldness, E,Working Alone

g. Dependent Variable: Thermal Sensation

Going to the next, the ANOVA which is an analysis of variance to investigate the differences of the predicting the outcome with the mean of variables. The F ratio illustrating the development for prediction of outcome from the model, named as Regression, with concern to the inaccuracy existed in the model, named as Residual. The development due to the association of regression model is very much greater than the inaccuracy existed in model. The F ratio from the initial model with 38.645 increases to the 19.895 in final model, this significantly explains the greater ability to predict the variables of outcome.

Table 4.4(k): Evaluation of Results for ANOVA of Multiple Linear Regression.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	29.101	1	29.101	38.645	.000[a]
	Residual	140.064	186	.753		
	Total	169.165	187			
2	Regression	46.557	2	23.278	35.124	.000[b]
	Residual	122.608	185	.663		
	Total	169.165	187			
3	Regression	56.486	3	18.829	30.746	.000[c]
	Residual	112.679	184	.612		
	Total	169.165	187			
4	Regression	60.267	4	15.067	25.319	.000[d]
	Residual	108.898	183	.595		
	Total	169.165	187			
5	Regression	63.027	5	12.605	21.615	.000[e]
	Residual	106.138	182	.583		
	Total	169.165	187			
6	Regression	67.228	6	11.205	19.895	.000[f]
	Residual	101.937	181	.563		
	Total	169.165	187			

a. Predictors: (Constant), K

b. Predictors: (Constant), K, Level of Air Flow

c. Predictors: (Constant), K, Level of Air Flow, Level of Coldness

d. Predictors: (Constant), K, Level of Air Flow, Level of Coldness,

e. Predictors: (Constant), K, Level of Air Flow, Level of Coldness, E

f. Predictors: (Constant), K, Level of Air Flow, Level of Coldness, E, Working Alone

g. Dependent Variable: Thermal Sensation

In coefficients table of multiple regression, the model contains the coefficient (b) for each of the predictor that used to indicate its individual contribution to the dependant variable. The positive b value explaining a positive relationship between the predictor and outcome, whereas the negative b values shows the inverse relationship. In this case, the overall thermal sensation enhanced as the b value of constant to the variables increases.

Besides, the b values also demonstrate the extent on how each of the predictor influences the outcome while all the other predictors are keep constant. The standard errors and t-statistic are associated in identifying how the b values differs from zero within the model. The particular predictor is significantly contributed to the model when the association of t-test with b value is shown to be significant as the value of Sig. is less than 0.05. Thus, the smaller the Sig. value, the larger t-value and indicating the greater predictor.

From the magnitude of this case, the t-statistic of body part K is the greatest predictor which giving more impact to the overall thermal sensation. Although the b values and it significance values are essential to consider at, however the standardized coefficients of beta values are simpler to be interpreted, as these values are acting independently on the variables in a model. The standardized beta values giving out better view on the importance of predictor in a model, these values are weighed in standard deviation units and hence it outlined a direct comparison. In this case, the standardized beta values for body part K is greater than the other variables and can be concluded as the main parameter to overall thermal sensation if compared among other variables or parameters.

Table 4.4(l): Evaluation of Coefficient for Multiple Linear Regression.

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.891	.191		4.667	.000
	K	-.193	.031	-.415	-6.216	.000
2	(Constant)	1.861	.260		7.147	.000
	K	-.173	.029	-.371	-5.875	.000
	Level of Air Flow	-.218	.042	-.324	-5.132	.000
3	(Constant)	2.578	.307		8.392	.000
	K	-.144	.029	-.308	-4.919	.000
	Level of Air Flow	-.192	.041	-.286	-4.652	.000
	Level of Coldness	-.185	.046	-.254	-4.027	.000
4	(Constant)	2.769	.312		8.871	.000
	K	-.149	.029	-.320	-5.166	.000
	Level of Air Flow	-.193	.041	-.288	-4.748	.000
	Level of Coldness	-.135	.050	-.185	-2.714	.007
5	(Constant)	3.148	.355		8.874	.000
	K	-.148	.029	-.318	-5.179	.000
	Level of Air Flow	-.188	.040	-.280	-4.655	.000
	Level of Coldness	-.111	.050	-.153	-2.208	.028
	E	-.094	.043	-.133	-2.175	.031
6	(Constant)	2.681	.388		6.906	.000
	K	-.152	.028	-.327	-5.418	.000
	Level of Air Flow	-.160	.041	-.239	-3.923	.000
	Level of Coldness	-.098	.050	-.134	-1.962	.051
	E	-.129	.044	-.182	-2.913	.004
	Alone	.321	.118	.169	2.731	.007

a. Dependent Variable: Thermal Sensation

The Table 4.4(m) below records the number of participants and the percentage of the number of votes to the category of seven-point ASHRAE thermal scale.

Table 4.4(m): Evaluation of ASHRAE 7-point Scale with Libraries.

7-point Thermal Sensation Group			Library	
			Main Library	Za'ba Library
	-3	Count	0	2
		% within Library	0%	2.4%
	-2	Count	6	6
		% within Library	5.7%	7.3%
	-1	Count	34	25
		% within Library	32.1%	30.5%
	0	Count	43	30
		% within Library	40.6%	36.6%
	1	Count	19	19
		% within Library	17.9%	23.2%
	2	Count	4	0
		% within Library	3.8%	0%
	3	Count	0	0
		% within Library	0%	0%
Total		Count	106	82
		% of Total	56.4%	43.6%

On the other hand, the votes for thermal sensation in each of the library have been categorized into 3 group, as stated in interior space of ASHRAE 55, the votes below -0.5 were in cold sensation, the votes within -0.5 and +0.5 were in neutral thermal sensation, whereas the votes that above 0.5 were in hot sensation group. The range of groups were categorized according to the recommendation by ASHRAE as comfort range. (ASHRAE 55, 2010) Basically, the votes that fall within neutral group in Main Library and Za'ba Library were 43 and 30 respectively, which contributed 40.6% and 36.6% of satisfaction. However, the percentages calculated do not imply to the PPD, this was just to sort out the actual votes for comfort range among the participants.

Table 4.4(n): Evaluation of Votes of Participants over the Thermal Sensation

Overall Thermal Sensation Group		Library	
		Main Library	Za'ba Library
Cold	Count	40	33
	% within Library	37.7%	40.2%
	% of Total	21.3%	17.6%
Neutral	Count	43	30
	% within Library	40.6%	36.6%
	% of Total	22.9%	16.0%
Warm	Count	23	19
	% within Library	21.7%	23.2%
	% of Total	12.2%	10.1%
Total	Count	106	82
	% of Total	56.4%	43.6%

To the votes for average thermal sensation in each of the library is shown in Table 4.4(o), were -0.18 and -0.29 respectively, and an average votes for both libraries was -0.23. The votes indicating the perception of participants (PMV) towards the thermally environment condition at their working area in library, so the perceptual PMV for both library were sited within the standard. Since the PPD is a function of PMV, it can be used to calculate the PPD through the formula below. (Richard, 1998) The PMV calculated in Main Library and Za'ba Library were 5.701% and 6.946% respectively, while the average as an overall of the perceptual PPD was 6.324% fall within ASHRAE 55 Standard of less than 10% of dissatisfaction.

Equation 4.4(1): Formula for calculation of PMV range.

$$PMV = (0.303\, e^{-0.036M} + 0.028)\, L \quad \text{------------------------------} \quad (1)$$

(Fanger, 1970)

Equation 4.4(2): Formula for calculation of PPD rate.

$$PPD = 100 - 95e^{[-(0.3353PMV^4 + 0.2179PMV^2)]} \quad (2)$$

(Richard, 1998)

where

PMV = Predicted Mean Vote Index

M = Metabolism Rate

L = Thermal load (determined as the distinction between the internal heat production and the heat loss to the apparent environment)

**e = Euler's number (2.718)*

Table 4.4(o): Evaluation of Results for Average Thermal Sensation Votes in the Libraries.

Libraries	Main Library	Za'ba library	Total
Mean (PMV)	-0.18	-0.29	-0.23
Standard Deviation	0.924	0.987	0.951
PPD (%)	5.701	6.946	6.324
Number of Participants	106	82	188

CHAPTER 5.0

DISCUSSIONS

5.1 Effects on Thermal Environmental Parameters on Perceived Thermal Sensation

5.1.1 The relationship between air temperature, mean radiant temperature and perceived thermal sensation.

The air temperature, to be interpreted from the perceived responses of this research, is parallel to level of coldness (warmness) which aim to find out the sensation of students towards the air temperature. By referring the correlation from the table, e.g. a too low of temperature would be in mutual influence with low level of air humidity, high level of fresh and air flow. Consequently, the level of sleepiness would be decreased and easier to concentrate on work, eventually effort needed to produce work would be lesser.

The mean radiant temperature, practically associated with air temperature to achieve the average of suitable temperature of the surrounding environment, both acted together to be the reasonable measure in resulting environmental temperature. The effect of environmental temperature on thermal sensation is very direct in corresponding to the change in thermal sensation, which actually inclusive the combined effect of both mean radiant temperature and air temperature.

In short, the air temperature and mean radiant temperature acted together in performing to influence the occupants to feel the level of coldness, in order to bring negative correlation to level of humidity, but positive correlation to level of air freshness, and level of air flow. Hence, the thermal sensation will give negative influence to the level of sleepiness, difficulty of concentration and effort to produce work as well. In this study, the range of air temperature and mean radiant temperature are fall within recommended standard by ASHRAE 55.

5.1.2 The relationship between relative humidity and perceived thermal sensation

The relative humidity, to be interpreted from the perceived responses of this research, is parallel to level of air humidity which aim to find out the sensation of students towards the percentage of humidity. By referring the correlation from the table, e.g. a too low level of air humidity would be in mutual effect with feeling of hot and stuffy air. However, level of humidity found to be not relevant much on self-assessed productivity variables, which means the productivity of students would not be influenced solely depend on relative humidity towards the perceptual thermal sensation. In short, the relative humidity having positive correlation with the level of coldness and air flow.

In addition, there are also other diseases or symptoms will be arose from the uncomfortable range of relative humidity. If the relative humidity fall under 20%, a too dry condition may cause irritation which might makes skin becomes dry and cracks. Nevertheless, at high humidity level as the recorded measurement in this research which is over 60%, this would affected on human comfort and physiological effect indirectly. A high humidity level decreases the evaporative cooling potential of human skin, but this could be solved by thermoregulation, body will diffuse sweat over the skin surface to make evaporation takes place. Therefore, the occupants might result in sweating. (Givoni, 1997)

In this study, the participants have been found that they didn't experience any physiological responses such as sweating or thermally uncomfortable sensation due to relative humidity. This could be said that the environment condition is fall within satisfied level by occupants, even though the measurement has revealed the relative humidity level were higher than standard suggested.

5.1.3 The relationship between air velocity and perceived thermal sensation

The air velocity, to be interpreted from the perceived responses of this research, is parallel to level of air freshness and draughtiness which aim to find out the sensation of students towards the air flow existed in library. By referring the correlation from the table, e.g. a too low level of air freshness and air flow rate (stuffy and still air) would be in mutual influence with feeling hot. Consequently, the level of sleepiness would be increased and harder to concentrate on work, eventually more effort needed to produce required work. In short, level of air freshness and air flow spread positive correlation to the level of coldness and effort needed, but negative correlation to the level of sleepiness and difficulty in concentration.

In addition, there are also other effects or symptoms might be arose from the uncomfortable range of air velocity. If the air velocity fall lower than 0.3 m/s or higher than 0.8 m/s as stated in ASHRAE 55 Standard, occupants might experience hard to breathe due to stuffy air or too draughty air. In this study, the measurement of velocity recorded a far lower than 0.3 m/s, however the major votes from participants were still ranked within the neutral thermal sensation. This means that the environment condition is fall within satisfied level by occupants, even though the measurement has revealed the air velocity level were a lot lower than standard recommended.

5.2 The relationship between localised body sensation and perceived thermal sensation

Localised body sensation is comprising body parts of: (A) Forehead; (B) Front of Neck; (C) Back of Neck; (D) Chest; (E) Back; (F) Upper Arms; (G) Lower Arms: (H) Hands; (I) Thigh; (J) Calf; and (K) Feet. From literature review acquired, the body parts i.e. neck, hands and feet are most sensitive parts with compared to all the other parts of the body to the thermal environment that focuses on the significant impact of thermal comfort. From the table 13, localised body sensation is significant to the reading of thermal sensation, whereas the front of neck revealed the direct relationship to have impact on thermal sensation. Besides, the back, upper arms, lower arms, hands, calf and feet demonstrated the two-tailed results in the table, and feet is the most significant one. The results shown is in parallel with the previous studies.

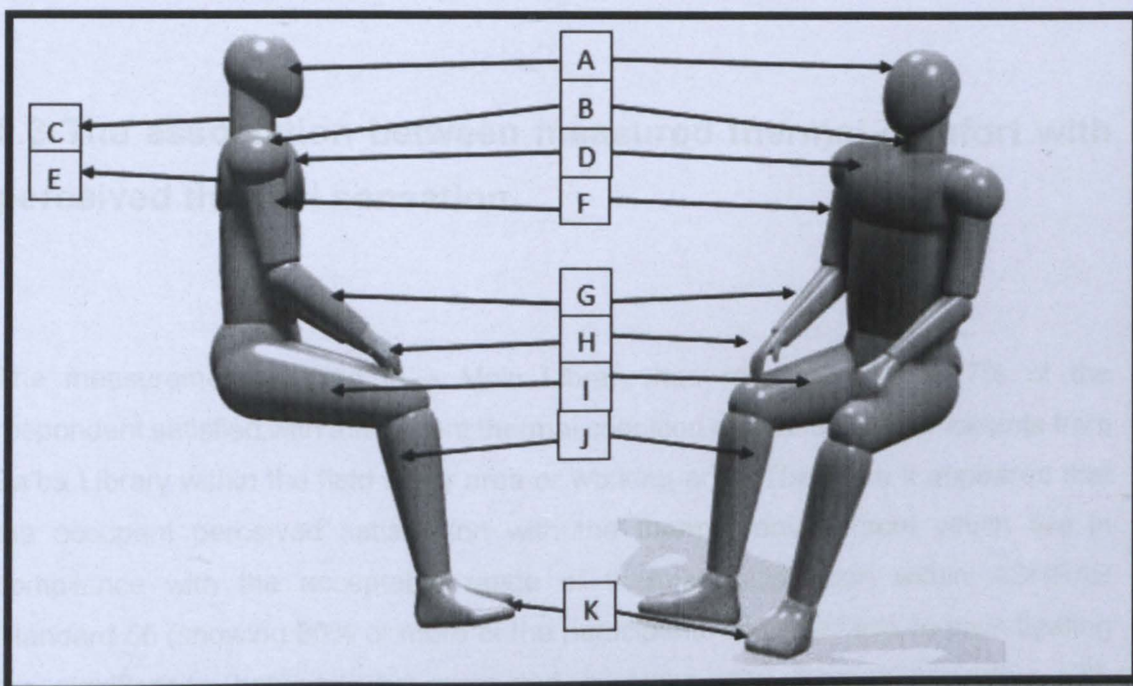

Figure 5.2: The localised body parts for thermal sensation measurement.
(Source: Human Model Sketch. Retrieved from: http://galleryhip.com/human-model-sketch.html)

By correlating this three parts with other variables, it have been found that the high sensitivity of this three body parts toward thermal sensation are positively correlated to level of coldness and air flow. This indicating that the three body parts are greatly influenced by air temperature and air velocity.

The average reading of measured air temperature and the perceived level of coldness were accounted as within range of thermally comfort and neutral thermal sensation. Meanwhile, although the average reading of measured air velocity were recorded lower than ASHRAE 55 standard of thermal comfort, however the majority perceived level of air flow were reported within neutral thermal sensation range as thermally comfort. Since, the two main parameters i.e. air temperature and air velocity, which were affected the three most sensitive body parts i.e. neck, hands and feet were ranked as neutral thermal sensation, thus these body parts have claimed as thermally comfort.

5.3 The association between measured thermal comfort with perceived thermal sensation.

The measurement studied in a Main Library has revealed that 94.7% of the respondent satisfied with the current thermal condition and 92.6% of participants from Za'ba Library within the field study area or working area. Therefore it appeared that the occupant perceived satisfaction with the thermal environment which are in compliance with the acceptable range of thermal satisfaction within ASHRAE Standard 55 (showing 80% or more of the participants are satisfied). In investigating the significance between the measured environmental thermal sensation with perceived thermal sensation, it shows the all measured environment thermal comfort parameters which are air temperature, mean radiant temperature, relative humidity and air velocity were demonstrated a significant association with the perceived variables i.e. demography information, localised body sensation, thermal environment sensation and the self-assessed productivity parameters.

The average measured air temperature and mean air temperature were found to be in compliance with the standard, whereas the average relative humidity was discovered to be higher than standard and air velocity was lower than recommended standard. However, the relevant perceived responses such as level of coldness, level of humidity, level of air freshness and level of air flow were presented to be lied within range of satisfaction. Furthermore, the PMV and PPD for both measured records and perceived responses were fall within -0.5 to 0.5 and 10% respectively as recommended in ASHRAE 55 standard. Therefore, by associating the measured data into perceived sensation records, the final results can be more affirmed and validated.

5.4 The relationship between self-assessed productivity parameters and overall thermal sensation.

From the previous literature review studied, the productivity loss declared to be influenced by the nature of the working task (Wyon, 2013), however this results from this research revealed the non-correlation between this two variables from the Table 4.4(i). Thus, the simulated tasks was assigned to the participants regarding to their working nature have been chosen, is just for the participants themselves to stimulate the rate of productivity if compared to normal days, but included the results of test in estimating their performance of task.

From the Table 4.4(i), learning productivity was significantly correlated to level of effort needed, difficulty of concentration, rate of sweat, level of sleepiness, level of air freshness and air flow, perceived thermal sensation and level of coldness. Rate of productivity was highly and positively correlated to level of effort, which means the more effort paid, the higher learning productivity. Furthermore, the level of sleepiness and difficulty of concentration have also impacted a negative correlation with learning productivity rate, indicating the more alert will be easier to concentrate which created a better or effective learning productivity. In addition from view of environmental parameters, the parameters are having positive correlation with learning productivity as well, e.g. the higher temperature that comes along with stuffy air and still air, will bring to a more extensive sweating rate, and consequently results in a lower productivity rate. This implying directly of the perceived thermal sensation is affecting the rate of productivity towards students. The results varies from the literature review achieved, whereby air velocity and air temperature were giving significance to rate of productivity , instead of relative humidity as stated by (Kosonen & Tan, 2004). From the Table 5.4(a) to Table 5.4(d), the highest percentage of participants who felt productive when they are in zero perceived thermal sensation, moderate level of coldness, moderate level of air freshness and draughtiness.

Table 5.4(a): Evaluation of Results for Average Productivity Votes with Respect to the Perceived Thermal Sensation.

Perceived Thermal Sensation	Mean	N	% of Total Sum
-3	5.00	2	.9%
-2	5.50	12	6.2%
-1	6.36	59	34.9%
0	5.62	73	38.2%
1	5.00	38	17.7%
2	5.50	4	2.1%
Total	5.71	188	100.0%

Table 5.4(b): Evaluation of Results for Average Productivity Votes with Respect to the Level of Coldness.

Level of coldness	Mean	N	% of Total Sum
3	4.75	12	5.3%
4	6.48	21	12.7%
5	5.39	75	37.7%
6	6.00	43	24.0%
7	5.44	25	12.7%
8	6.67	6	3.7%
9	7.00	6	3.9%
Total	5.71	188	100.0%

Table 5.4(c): Evaluation of Results for Average Productivity Votes with Respect to the Level of Freshness.

Level of Freshness	Mean	N	% of Total Sum
1	5.80	10	5.4%
2	6.00	3	1.7%
3	5.00	21	9.8%
4	4.56	16	6.8%
5	5.76	70	37.6%
6	5.70	30	15.9%
7	6.47	15	9.0%
8	6.00	17	9.5%
9	7.50	4	2.8%
10	8.00	2	1.5%
Total	5.71	188	100.0%

Table 5.4(d): Evaluation of Results for Average Productivity Votes with Respect to the Air Flow Rate.

Air Flow Rate	Mean	N	% of Total Sum
0	6.00	1	.6%
1	4.43	7	2.9%
2	6.00	1	.6%
3	4.60	15	6.4%
4	5.45	11	5.6%
5	5.68	110	58.2%
6	6.25	16	9.3%
7	6.61	23	14.2%
8	6.00	2	1.1%
9	6.00	2	1.1%
Total	5.71	188	100.0%

5.6 Findings

Due to large difference from person to person, it is hard to satisfy everyone within the same thermal environment condition, thus the comfortable thermal criteria must be maintained. There are many guidelines provided standard for recommended range of parameters for thermal comfort, i.e. for study area, air temperature and mean radiant temperature should maintained within 23.0-26.0°C (ASHRAE 55, 2010) , relative humidity suggested to lies between 30-70% (ISO 7730, 2006), and air velocity at about 0.15 m/s (ASHRAE 55, 2010). However, at other areas apart from study area, such as material storage areas would has to follow some other specific recommended standard which the air temperature and mean radiant temperature should be sited between 18.0-24.0°C, and a relative humidity level of between 40-55%. (Purafil Inc., 2004) The field measurement was reported the average reading of air temperature, mean radiant temperature, relative humidity and air velocity were 23.95°C , 23.92°C, 67.83% and 0.03 m/s in Main Library and 24.72°C , 24.34°C, 71.34 % and 0.01 m/s in Za'ba Library respectively.

Based on the thermal environment data gathered and calculated from the field measurement, the air temperature and mean radiant temperature found to be in compliance with the standard stated, i.e. ASHRAE 55 and ISO 7730. However, the percentage rate of relative humidity revealed that were higher than standard, whereas the air velocity has reported were lower than standard. Failed of compliancy for these two parameters might cause some uncomfortable feel or health symptoms and got high percentage of dissatisfaction (PPD), but the occupants are neither get interfered in overall thermal sensation nor susceptible to any uncomfortable feel and health symptoms, and the results for both Predicted Mean Vote (PMV) and PPD disclosed were within range. Plus, the difference coordination of thermal criteria (relative humidity, air velocity, clothing value, metabolism rate, etc.) can lead to similar PMV results. The PMV values is useful to estimate productivity loss, as set points for typing and thinking tasks that helps to evaluate productivity loss in different climates but nonetheless further verification is required. Hence, this indicated the two parameters have coordinated to contributed the sufficient range to acceptable thermal comfort, even though it were not comply with the recommended standard.

On the other hand, the results shown from relevant parameters in perceived thermal sensation, i.e. the level of coldness (air temperature and mean radiant temperature), the level of humidity (relative humidity) and the level of air freshness and air flow (air velocity), the major votes of these parameters were all lies within neutral thermal comfort range and no either uncomfortable feel not health symptoms expressed. The PMV and PPD deduced from the perceived thermal sensation votes were in compliance with the recommended standard as well.

In addition, the association of measured environmental PMV and PPD with the perceived sensation of PMV and PPD were both fall within the standard range to achieved an acceptable overall thermal sensation, of which:

1. the PMV is located between range of -0.5 and +0.5, and PPD of less than 10% (ASHRAE 55, 2010)
2. the PMV is located between range of -0.7 and +0.7, and PPD of less than 15% (ISO 7730, 2006)

In terms of human factors or demography, as referred to previously in Chapter 2.3, the gender, rate of BMI and clothing value would affect the perceived thermal sensation votes. However, it didn't demonstrated any great significant correlation in this research, these factors only revealed a very low significant correlation to the perceived thermal sensation.

Moreover, there are some other parameters were found to be correlated among each other, to have influence on some important parameters. For instance, the level of coldness, air freshness and air flow would lead to the higher temperature on certain parts of body such as neck, hands and feet. These locations of body parts would bring an effect to perceived thermal sensation, if it were having too high or too low of temperature or air flow rate.

Through this research, the thermal condition in library did yield effects to the occupants in library. Besides, the predictors or variables that found to impact on the perceived thermal sensation were localized sensation body part K (Feet), the level of air flow, the level of coldness, body part E (Back) and working alone factor. Out of these parameters, the feet presented the most significant influence on the perceived thermal sensation with respect to localized body sensation parameter, whereas the level of air flow and coldness have been revealed its significance to perceived thermal sensation in respect to thermal environmental parameters. Besides, working alone factor was the only one among the demography parameters which found to affect the perceived thermal sensation.

Apart from that, the productivity of work was found to be significantly correlated to level of air freshness and air flow and level of coldness, which indicating it would be influenced by air temperature and air velocity. This directly implying of the perceived thermal sensation affected the rate of productivity towards students, and the most productive of task happened when the participants were in zero perceived thermal sensation, moderate level of coldness, moderate level of air freshness and air flow rate.

CHAPTER 6.0

CONCLUSION AND RECOMMENDATIONS

This research presents a study that was carried out to study of interactions between the students' perception on thermal sensation could lead to an effect to the working productivity within study area in libraries. The goals of study was to identify the pattern and effects of thermal environmental parameters on thermal sensation, and correlate the relationship of perceptual responses of students with the thermal sensation within working area in library, and these parameters were successfully included to give out effect, in parallel to the thermal sensation votes.

Besides, this research also aimed to indicate the relationship between measured thermal sensation with the perceived thermal sensation of students in library, whereby the PMV and PPD rate for both the measured and perceived thermal sensation have found to be sited within the recommended standards.

Also, the most significant parameters on overall thermal sensation in library and related to work productivity of students had been outlined. The body part K which is the feet area found to have great effect on perceived thermal sensation in terms of localised body sensation, and the level of air flow and level of coldness demonstrated the significance of air velocity and air temperature toward perceived thermal sensation in terms of thermal environmental parameters, and working alone did promoted effect in terms of demography factors.

Table 6.0: Summary table for conclusions by referring to objectives.

OBJECTIVES	RESULTS	CONCLUSION
1. Identify the pattern & effects of thermal environmental parameters on thermal sensation.	-The air temperature and mean radiant temperature complied to the standards. -The relative humidity and air velocity didn't comply to the recommended standards.	Achieved.
2. Explain the relationship of perceived responses of students to the overall thermal sensation.	The relevant parameters found to be satisfied by occupants from the perceived responses collected. -The Level of Coldness (Air Temperature & Mean Radiant Temperature) -The Level of Humidity (Relative Humidity) -The Level of Air Freshness & Air Flow (Air Velocity)	Achieved.
3. Investigate the relationship between measured and perceived thermal sensation of students.	The measured thermal sensation is parallel with the perceived thermal sensation, as the PMV and PPD are both sited within the standard range.	Achieved.
4. Recommend the most significant parameters on overall thermal sensation with learning productivity of students.	The most significant parameters for each of the groups of variables on overall sensation found in library: -Localised Body Sensation: Body part K (feet), -Thermal Environmental Parameters: Air Velocity and Air Temperature -Demography Parameter: Working alone	Achieved.

6.1 Recommendations

The study area in a library is very important for student to perform in their task, thus a good thermal environment is always essential to increase the productivity of work. Even though the PMV and PPD of two libraries were situated within recommended standard, however improvements can be made through effort on enhancing the relative humidity level and air velocity rate which were found not meeting the recommended standards. Moreover, working alone factor is also found to be impacted on the perceived thermal sensation. Thus, few recommendations can be proposed that suit remedies to the problem.

6.1.1 Low Cost Recommendation

From previous study (Mishra and Ramgopal, 2014), student is always welcoming the high velocities of air flow, so a mechanical fans can be added but with slow and uniform speed of air velocity would be more helpful. For example, the Big Ass Fans type of large and wide fan could be installed in library as shown in Figure 6.1.1. This type of fan intended to circulate air all through high spaces, wide spaces, for example, sports hall and also other sound-sensitive spaces. It aids to enhance comfort also in workplaces and other littler spaces, due to its accessible in an assortment of sizes, smooth and noiseless design. Furthermore, it likewise to work as one with AC frameworks to both give this cooling impact and equally distribute air all throughout the space, it can also enhance 5.6°C cooling impact even without existence of AC. Hence, the executive can use this energy-efficient fans to enhance library occupants' thermal sensation, without sparing big amount of money.

Figure 6.1.1: Example of Big Ass Fans be locate in a wide and high area.

(Source: Big Ass Fans.)

On the other hand, to meet the control of working factor, the well-planned arrangement of space for students' study tables is essential. Since the working alone student will have a cooler thermal sensation, those segmented tables may be arranged far from the point under air distribution outlet point, or place nearby the edges of the area. In contrast, those discussion tables or tables for students in group who are usually feel warmer than those are working alone, could be placed nearer to the air distribution points.

6.1.2 Medium Cost Recommendation

Secondly, the regular maintenance with proper adjustments on the HVAC system could help in providing a better thermally comfort environment to the occupants. The appropriate level of coldness and airflow rate supplied by the HVAC system should be adjusted and maintained regularly, so it could meet the satisfaction of occupants. Those filters, condenser coils, refrigerant level, and fan problems should always been checked. The clogged filters, polluted coils, ineffective fan and low level or leakage of refrigerant would directly affected the quality of air to be supplied (Arista, 2015).

Besides, balancing a central-air system can be done through maintenance and adjustment, by means air is being cooled and distributed equally have to be ensured. The balance air distribution would enhance the thermal environment performance and also the energy efficiency. The occupants would then easily achieved stable and thermally neutral state (Arista, 2015).

There are also a lot of unexpected manners that occupants will adapt themselves to the thermal environment to the extent of their suitability. Hence, the goal of the future studies should not be just to find some ideal temperature which would make all occupants feel comfortable. As the field surveys have demonstrated the existence of adaptive comfort theory with the relative humidity level and air velocity rate were not in compliance to the recommended standards, yet the perceived thermal responses, PMV and PPD were fell within standard range. This concluded majority of the occupants could achieve their comfort over a broad ranges of temperature or other thermal conditions when there is given suitable avenues of adaptation. In recent studies, occupants found to have adapted to the prevalent thermal conditions and demonstrated high levels of acceptance of their thermal environment. (Mishra and Ramgopal, 2014)

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APPENDICES

Appendix A

I am final year students from Department of Building Surveying, Faculty of Built Environment, University of Malaya, is going to do my final year project with a research topic " Students' Perception on Thermal Sensation in Libraries. The purpose of this research is to study the students' perception on thermal sensation in libraries. All the information gathered will be kept CONFIDENTIAL and will be used for educational purposes only.

Library : ____________________

Session :

	Morning		Afternoon

General Information

1) Gender

	Male		Female

2) Age:__________

3) Height: cm , Weight: kg

4) How many hours have you been slept in last night?

	0 – 2 hours		2 – 4 hours
	4 – 6 hours		6 – 8 hours
	> 8 hours		

If compared with your routine sleeping time habit, is that considered to be enough sleep or rest for you? *(Please tick only one)*

	Yes		No

If no, why?

____

5) What time did you taken your last meal?

Breakfast: ______________; Lunch: ______________

6) What type of work are you doing now? *(You may tick more than one)*

	Logical thinking (i.e solving equations, analysing data, etc)
	Work related to text-typing (i.e editing assignment, writing up assignment, etc)

7) Are you working alone? *(Please tick only one)*

	Yes		No

Right now, **I am wearing:**

(Please tick accordingly in each section)

Shirts and Blouse

- ○ Sleeveless
- ○ Short sleeved, cotton
- ○ Long sleeved, cotton
- ○ Long sleeved, flannel

Dresses and Skirts

- ○ Skirt (thin garment)
- ○ Skirt (thick garment)
- ○ Short sleeved shirtdress
- ○ Short sleeved shirtdress (thin)
- ○ Short sleeved shirtdress (thick)

Trousers

- ○ Sport shorts
- ○ Walking shorts
- ○ Straight trousers (thin)
- ○ Straight trousers (thick)

Underclothing

- ○ Men's brief
- ○ Panties
- ○ Bra
- ○ T-shirt
- ○ Full slip
- ○ Half slip
- ○ Long underwear top
- ○ Long underwear bottom

Vests and Jackets

- ○ Sleeveless vest (thin)
- ○ Sleeveless vest (thick)
- ○ Single-breasted suit jacket
- ○ Double-breasted suit jacket

Sweaters

- ○ Sleeveless
- ○ Long sleeved

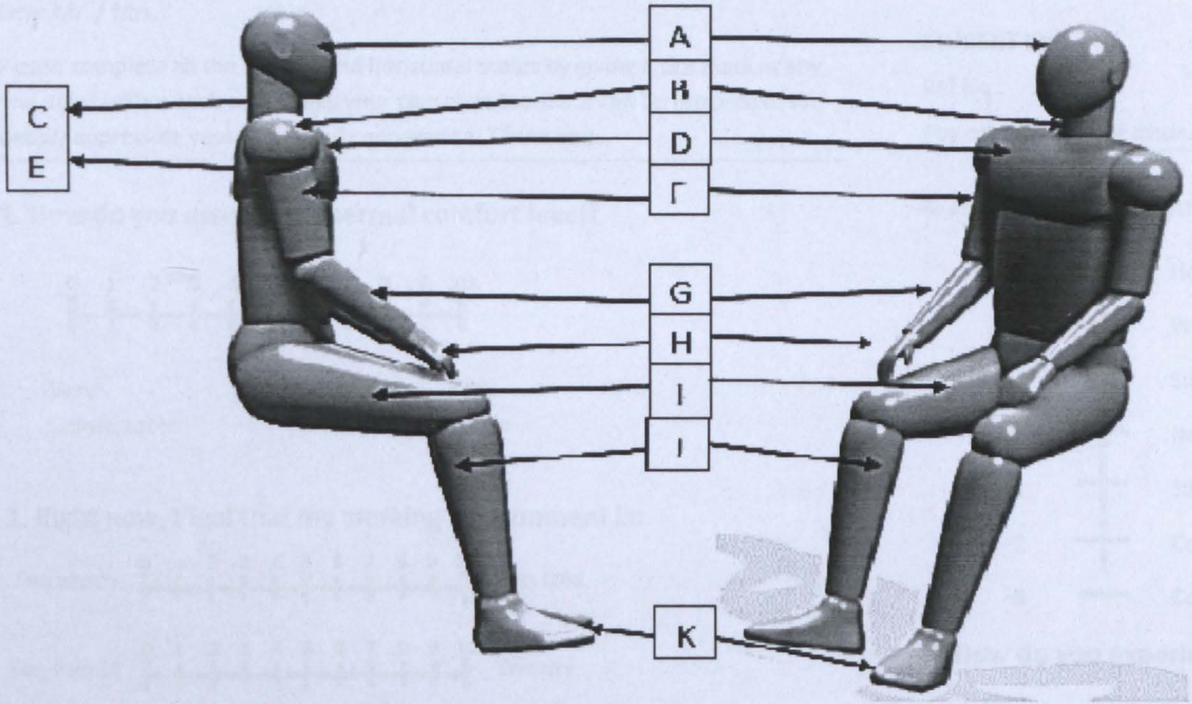
Footwear

- ○ Ankle-length socks
- ○ Calf-length socks
- ○ Knee socks
- ○ Panty hose
- ○ Shoes, thin
- ○ Shoes, thick
- ○ Boots

Others Clothing/ Wardrobe

- ○ Head scarves
- ○ Long/ neck scarves

How do you rate the thermal sensation at these locations of your body at the moment?



A (Forehead): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

B (Front of Neck): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

C (Back of Neck): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

D (Chest): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

E (Back): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

F (Upper Arms): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

G (Lower Arms): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

H (Hands): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

I (Thigh): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

J (Calf): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

K (Feet): Hot 0 1 2 3 4 5 6 7 8 9 10 Cold

THERMAL COMFORT SURVEY

Dear Mr. / Mrs.

Please complete all the vertical and horizontal scales by giving a tick mark at any one point within each scale. Only your complete feedback can be processed. We deeply appreciate your effort and cooperation. Thank you.

1. How do you assess the thermal comfort level?

0 1 2 3 4 5 6 7 8 9 10

Very Comfortable — Very Uncomfortable

2. Right now, I feel that my working environment is:

Too warm 0 1 2 3 4 5 6 7 8 9 10 Too cold

Too humid 0 1 2 3 4 5 6 7 8 9 10 Too dry

Air stuffy 0 1 2 3 4 5 6 7 8 9 10 Air fresh

Air still 0 1 2 3 4 5 6 7 8 9 10 Air drafty

3. Right now, I feel/ experience as follows:

Alert 0 1 2 3 4 5 6 7 8 9 10 Sleepy

Easy to concentrate 0 1 2 3 4 5 6 7 8 9 10 Hard to concentrate

STUDENT ID:

Ref No.:

Pay attention to the distinction between two options/ choices.

4. How do you rate your thermal sensation?

+3 Hot

+2 Warm

+1 Slightly warm

0 Neutral

-1 Slightly cool

-2 Cool

-3 Cold

5. How do you experience sweating or humid skin?

0 1 2 3 4 5 6 7 8 9 10

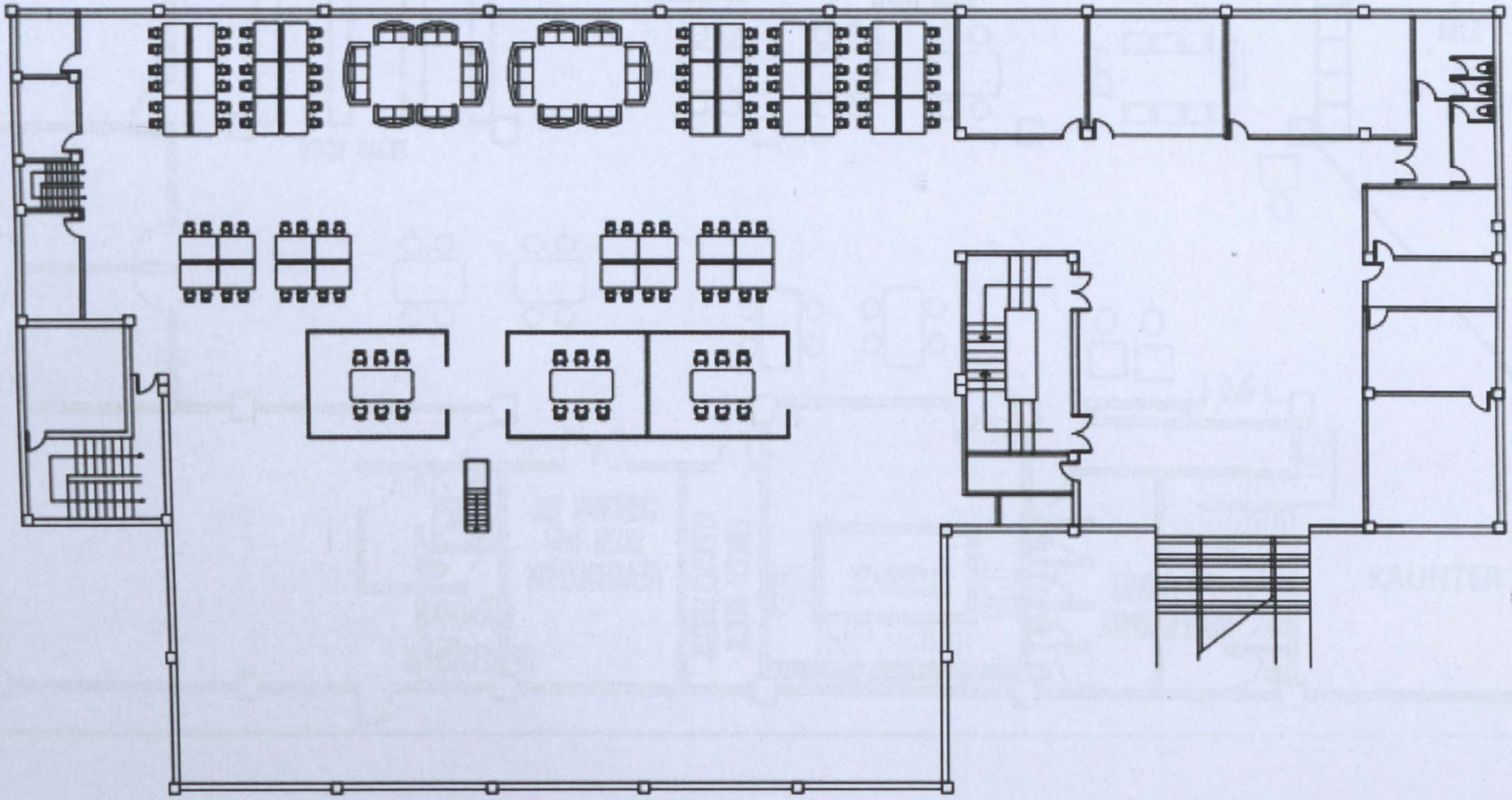
Extensively/ continuously — Not at all

6. How do you rate the completion of your tasks today?

Less Effort 0 1 2 3 4 5 6 7 8 9 10 Strong Effort

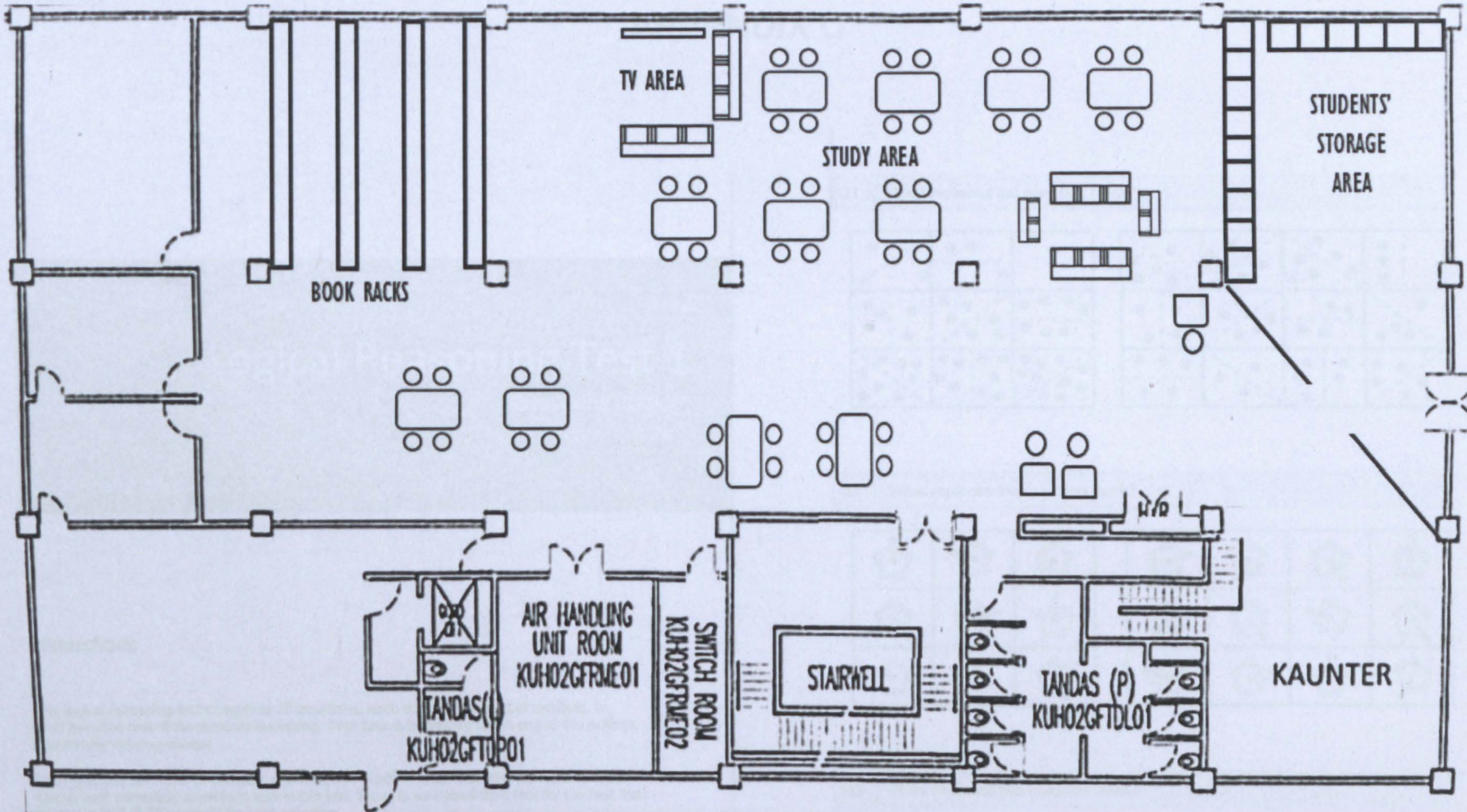
Less Productive 0 1 2 3 4 5 6 7 8 9 10 Very Productive

APPENDIX B



Collaborative Learning Area, Third Floor of Main Library, University of Malaya.

Not to Scale



Student Study Area, Second Floor of Za'ba Memorial Library, University of Malaya.

Not to Scale

APPENDIX C

Logical Reasoning Test 1

Questions Booklet

Difficulty: Medium

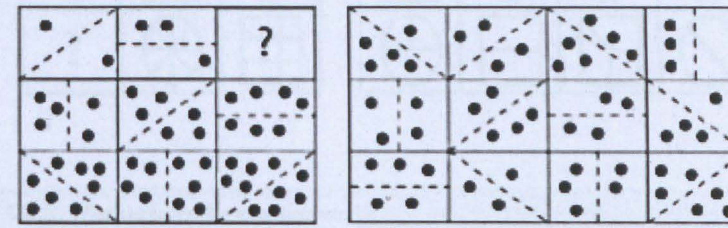
Instructions

This logical reasoning test comprises 15 questions, each containing a grid of symbols. In each question one of the symbols is missing. Your task is to choose which one of the options best fits the missing symbol.

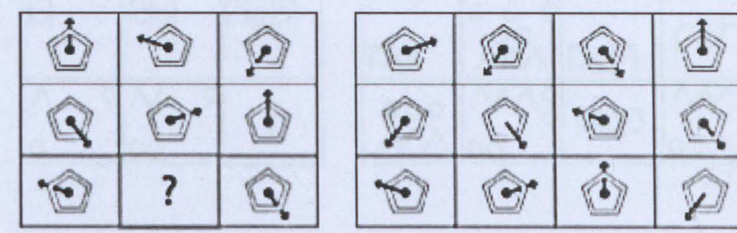
Each question will have 12 possible answers, one of which is correct. You will have to work quickly and accurately to perform well in this test. There is no overall time limit for the test, but there is a limit of 70 seconds for each question.

Try to find a time and place where you will not be interrupted during the test. The test will start on the next page

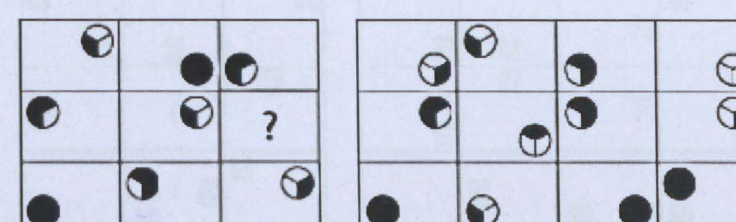
Q1 What replaces the question mark?



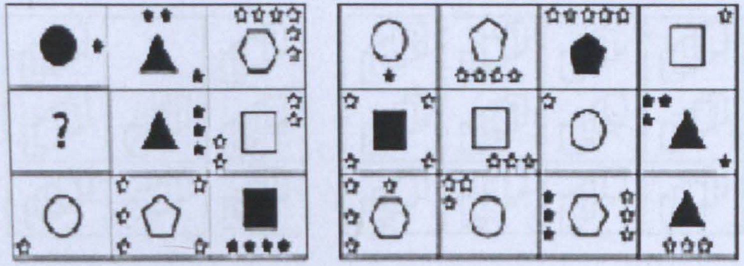
Q2 What replaces the question mark?



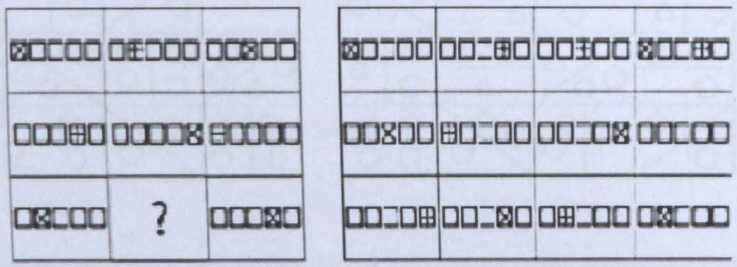
Q3 What replaces the question mark?



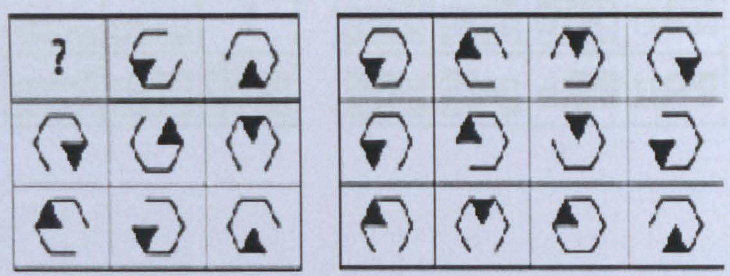
Q4 What replaces the question mark?



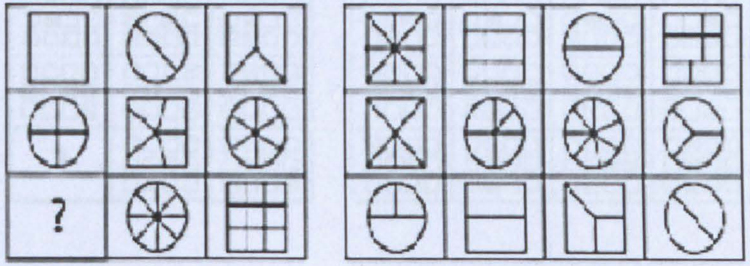
Q5 What replaces the question mark?



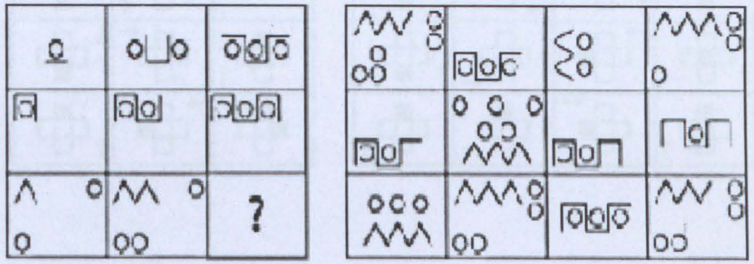
Q6 What replaces the question mark?



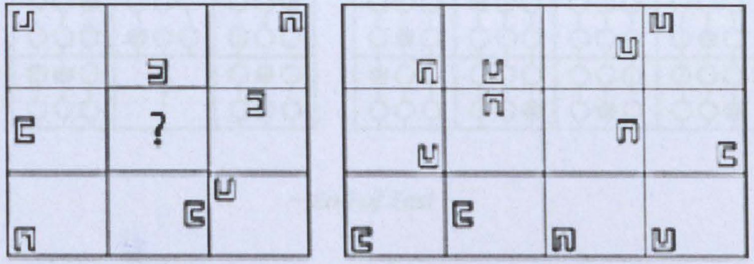
Q7 What replaces the question mark?



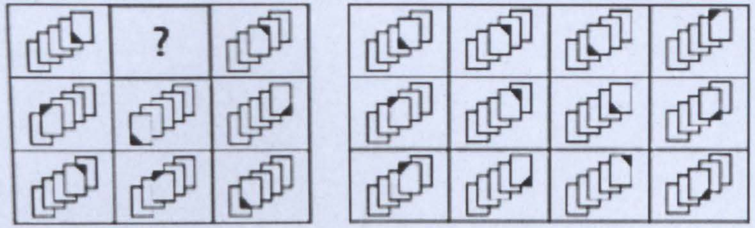
Q8 What replaces the question mark?



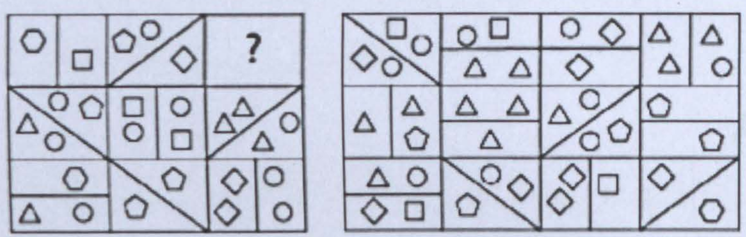
Q9 What replaces the question mark?



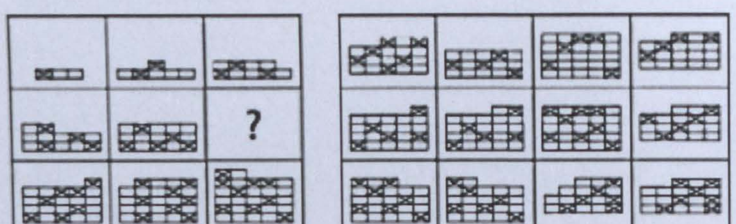
Q10 What replaces the question mark?



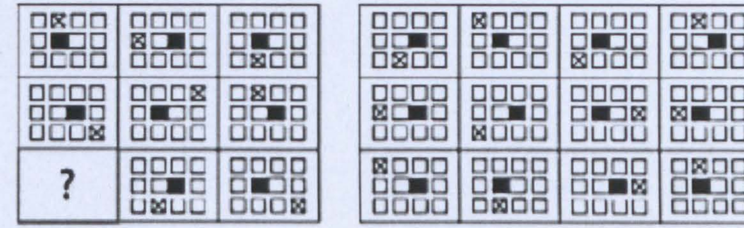
Q11 What replaces the question mark?



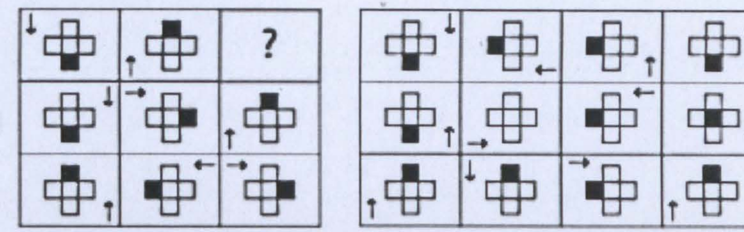
Q12 What replaces the question mark?



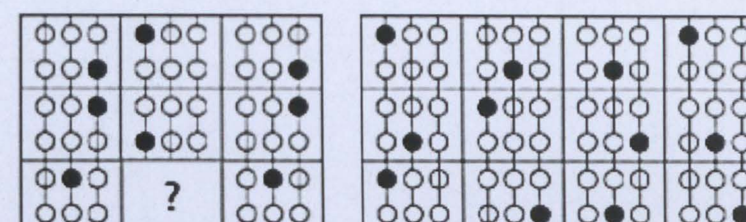
Q13 What replaces the question mark?



Q14 What replaces the question mark?



Q15 What replaces the question mark?



– End of Test –

APPENDIX D

Table 4.2(f) Correlation between thermal sensation variables.

		Body Part A	Body Part B	Body Part C	Body Part D	Body Part E	Body Part F	Body Part G	Body Part H	Body Part I	Body Part J	Body Part K	Level of Coldness	Level of Humidity	Level of Freshness	Level of Airflow	Level of Sleepiness	Concentration	TS	Sweat Rate	Effort Needed	Productivity
Body Part A	Pearson Correlation	1	.693**	.466**	.474**	.233**	.231**	.260**	.109	.380**	.234**	-.108	.073	-.008	.097	.187*	-.056	-.138	-.021	.074	.122	.230**
	Sig. (2-tailed)		.000	.000	.000	.001	.001	.000	.138	.000	.001	.139	.321	.909	.185	.010	.445	.058	.778	.314	.095	.002
Body Part B	Pearson Correlation	.693**	1	.652**	.476**	.269**	.205**	.316**	.013	.274**	.205**	-.037	.027	-.070	.181*	.350**	-.025	.054	-.159*	.282**	.177*	.325**
	Sig. (2-tailed)	.000		.000	.000	.000	.005	.000	.859	.000	.005	.616	.708	.338	.013	.000	.736	.464	.029	.000	.015	.000
Body Part C	Pearson Correlation	.466**	.652**	1	.160*	.364**	.331**	.393**	.034	.245**	.403**	.187*	.211**	-.159*	.071	.337**	-.059	.017	-.302**	.126	.221**	.249**
	Sig. (2-tailed)	.000	.000		.028	.000	.000	.000	.648	.001	.000	.010	.004	.030	.331	.000	.418	.818	.000	.085	.002	.001
Body Part D	Pearson Correlation	.474**	.476**	.160*	1	.441**	.203**	.134	.046	.239**	.031	-.196**	-.043	-.003	.037	.117	.087	.254**	.017	-.067	.015	-.002
	Sig. (2-tailed)	.000	.000	.028		.000	.005	.068	.530	.001	.677	.007	.555	.969	.616	.111	.233	.000	.815	.363	.839	.982
Body Part E	Pearson Correlation	.233**	.269**	.364**	.441**	1	.617**	.276**	.138	.126	.269**	.083	.179*	-.014	.111	.096	.124	.265**	-.194**	-.029	.096	.073
	Sig. (2-tailed)	.001	.000	.000	.000		.000	.000	.059	.085	.000	.257	.014	.846	.129	.191	.091	.000	.008	.695	.189	.319
Body Part F	Pearson Correlation	.231**	.205**	.331**	.203**	.617**	1	.352**	.208**	.284**	.437**	.347**	.323**	-.063	.039	.049	.227**	.128	-.284**	.109	.055	.128
	Sig. (2-tailed)	.001	.005	.000	.005	.000		.000	.004	.000	.000	.000	.000	.389	.591	.501	.002	.080	.000	.138	.452	.080
Body Part G	Pearson Correlation	.260**	.316**	.393**	.134	.276**	.352**	1	.398**	.405**	.402**	.146*	.442**	.068	.136	.228**	.080	-.025	-.237**	.064	.268**	.259**
	Sig. (2-tailed)	.000	.000	.000	.068	.000	.000		.000	.000	.000	.045	.000	.351	.062	.002	.274	.729	.001	.385	.000	.000
Body Part H	Pearson Correlation	.109	.013	.034	.046	.138	.208**	.398**	1	.363**	.325**	.346**	.303**	.000	.130	.083	-.077	-.097	-.277**	.128	.263**	.106
	Sig. (2-tailed)	.138	.859	.648	.530	.059	.004	.000		.000	.000	.000	.000	.990	.076	.260	.296	.184	.000	.080	.000	.146
Body Part I	Pearson Correlation	.380**	.274**	.245**	.239**	.126	.284**	.405**	.363**	1	.680**	.236**	.199**	-.095	.244**	.293**	.142	-.084	-.106	.094	.158*	.124
	Sig. (2-tailed)	.000	.000	.001	.001	.085	.000	.000	.000		.000	.001	.006	.194	.001	.000	.052	.252	.148	.201	.030	.091
Body Part J	Pearson Correlation	.234**	.205**	.403**	.031	.269**	.437**	.402**	.325**	.680**	1	.535**	.166*	.089	.105	.214**	.253**	.047	-.247**	-.032	.157*	.106
	Sig. (2-tailed)	.001	.005	.000	.677	.000	.000	.000	.000	.000		.000	.023	.227	.153	.003	.000	.526	.001	.660	.032	.146
Body Part K	Pearson Correlation	-.108	-.037	.187*	-.196**	.083	.347**	.146*	.346**	.236**	.535**	1	.267**	-.100	.079	.135	.075	-.113	-.415**	.051	.174*	.163*
	Sig. (2-tailed)	.139	.616	.010	.007	.257	.000	.045	.000	.001	.000		.000	.173	.279	.066	.308	.121	.000	.489	.017	.026
Level of Coldness	Pearson Correlation	.073	.027	.211**	-.043	.179*	.323**	.442**	.303**	.199**	.166*	.267**	1	-.227**	.252**	.184*	-.164*	-.200**	-.389**	-.018	.254**	.141
	Sig. (2-tailed)	.321	.708	.004	.555	.014	.000	.000	.000	.006	.023	.000		.002	.000	.012	.024	.006	.000	.811	.000	.053
Level of Humidity	Pearson Correlation	-.008	-.070	-.159*	-.003	-.014	-.063	.068	.000	-.095	.089	-.100	-.227**	1	-.189**	-.085	.075	-.107	.159*	-.045	-.001	.032
	Sig. (2-tailed)	.909	.338	.030	.969	.846	.389	.351	.990	.194	.227	.173	.002		.009	.247	.305	.142	.029	.539	.989	.667
Level of Freshness	Pearson Correlation	.097	.181*	.071	.037	.111	.039	.136	.130	.244**	.105	.079	.252**	-.189**	1	.613**	-.185*	-.131	-.314**	.154*	.129	.240**
	Sig. (2-tailed)	.185	.013	.331	.616	.129	.591	.062	.076	.001	.153	.279	.000	.009		.000	.011	.073	.000	.035	.078	.001
Level of Airflow	Pearson Correlation	.187*	.350**	.337**	.117	.096	.049	.228**	.083	.293**	.214**	.135	.184*	-.085	.613**	1	-.175*	-.121	-.374**	.082	.272**	.297**
	Sig. (2-tailed)	.010	.000	.000	.111	.191	.501	.002	.260	.000	.003	.066	.012	.247	.000		.016	.099	.000	.261	.000	.000
Level of Sleepiness	Pearson Correlation	-.056	-.025	-.059	.087	.124	.227**	.080	-.077	.142	.253**	.075	-.164*	.075	-.185*	-.175*	1	.629**	.029	-.152*	-.232**	-.328**
	Sig. (2-tailed)	.445	.736	.418	.233	.091	.002	.274	.296	.052	.000	.308	.024	.305	.011	.016		.000	.688	.037	.001	.000
Concentration	Pearson Correlation	-.138	.054	.017	.254**	.265**	.128	-.025	-.097	-.084	.047	-.113	-.200**	-.107	-.131	-.121	.629**	1	.017	-.126	-.394**	-.475**
	Sig. (2-tailed)	.058	.464	.818	.000	.000	.080	.729	.184	.252	.526	.121	.006	.142	.073	.099	.000		.817	.084	.000	.000
TS	Pearson Correlation	-.021	-.159*	-.302**	.017	-.194**	-.284**	-.237**	-.277**	-.106	-.247**	-.415**	-.389**	.159*	-.314**	-.374**	.029	.017	1	-.109	-.243**	-.206**
	Sig. (2-tailed)	.778	.029	.000	.815	.008	.000	.001	.000	.148	.001	.000	.000	.029	.000	.000	.688	.817		.137	.001	.005
Sweat Rate	Pearson Correlation	.074	.282**	.126	-.067	-.029	.109	.064	.128	.094	-.032	.051	-.018	-.045	.154*	.082	-.152*	-.126	-.109	1	.219**	.352**
	Sig. (2-tailed)	.314	.000	.085	.363	.695	.138	.385	.080	.201	.660	.489	.811	.539	.035	.261	.037	.084	.137		.003	.000
Effort Needed	Pearson Correlation	.122	.177*	.221**	.015	.096	.055	.268**	.263**	.158*	.157*	.174*	.254**	-.001	.129	.272**	-.232**	-.394**	-.243**	.219**	1	.762**
	Sig. (2-tailed)	.095	.015	.002	.839	.189	.452	.000	.000	.030	.032	.017	.000	.989	.078	.000	.001	.000	.001	.003		.000
Productivity	Pearson Correlation	.230**	.325**	.249**	-.002	.073	.128	.259**	.106	.124	.106	.163*	.141	.032	.240**	.297**	-.328**	-.475**	-.206**	.352**	.762**	1
	Sig. (2-tailed)	.002	.000	.001	.982	.319	.080	.000	.146	.091	.146	.026	.053	.667	.001	.000	.000	.000	.005	.000	.000	

Table 4.2(g): Correlations between Demography Parameters and Perceived Thermal Sensation.

		TS	BMI	Age	Clo. Value	Library	Session	Gender	Sufficient Sleep Hours	Meal	Work	Alone	Self-Evaluated Factors	Localised Body Part Factors	TE Sensation Factors
TS	Pearson Correlation	1	-.072	-.078	.121	-.059	.030	.124	.021	.079	-.066	.185*	-.175*	-.323**	-.493**
	Sig. (2-tailed)		.325	.289	.097	.419	.686	.089	.778	.284	.371	.011	.016	.000	.000
BMI	Pearson Correlation	-.072	1	.160*	.117	-.071	-.018	-.072	-.186*	-.005	-.176*	.013	.026	.026	-.012
	Sig. (2-tailed)	.325		.028	.109	.334	.812	.325	.011	.942	.016	.858	.723	.722	.869
Age	Pearson Correlation	-.078	.160*	1	.046	-.195**	-.058	-.075	-.159*	.047	.113	-.272**	-.010	-.102	.138
	Sig. (2-tailed)	.289	.028		.533	.007	.430	.307	.029	.524	.121	.000	.896	.165	.058
Clo. Value	Pearson Correlation	.121	.117	.046	1	.068	-.101	.173*	-.205**	-.072	.004	.175*	-.056	-.082	-.012
	Sig. (2-tailed)	.097	.109	.533		.352	.169	.017	.005	.325	.958	.016	.449	.264	.866
Library	Pearson Correlation	-.059	-.071	-.195**	.068	1	.104	.038	-.225**	-.079	-.070	.021	-.131	-.068	.196**
	Sig. (2-tailed)	.419	.334	.007	.352		.157	.609	.002	.280	.343	.770	.073	.351	.007
Session	Pearson Correlation	.030	-.018	-.058	-.101	.104	1	-.011	.059	-.117	.097	-.032	.026	.008	.005
	Sig. (2-tailed)	.686	.812	.430	.169	.157		.881	.422	.110	.185	.663	.725	.910	.945
Gender	Pearson Correlation	.124	-.072	-.075	.173*	.038	-.011	1	-.146*	.010	-.047	.163*	-.031	-.256**	-.215**
	Sig. (2-tailed)	.089	.325	.307	.017	.609	.881		.046	.888	.519	.025	.677	.000	.003
Sufficient Sleep Hours	Pearson Correlation	.021	-.186*	-.159*	-.205**	-.225**	.059	-.146*	1	.058	.018	.077	-.103	.122	-.240**
	Sig. (2-tailed)	.778	.011	.029	.005	.002	.422	.046		.428	.807	.292	.159	.095	.001
Meal	Pearson Correlation	.079	-.005	.047	-.072	-.079	-.117	.010	.058	1	-.156*	.053	.046	.013	.010
	Sig. (2-tailed)	.284	.942	.524	.325	.280	.110	.888	.428		.032	.473	.529	.857	.891
Work	Pearson Correlation	-.066	-.176*	.113	.004	-.070	.097	-.047	.018	-.156*	1	-.164*	-.030	.123	.058
	Sig. (2-tailed)	.371	.016	.121	.958	.343	.185	.519	.807	.032		.025	.680	.093	.433
Alone	Pearson Correlation	.185*	.013	-.272**	.175*	.021	-.032	.163*	.077	.053	-.164*	1	-.159*	.074	-.278**
	Sig. (2-tailed)	.011	.858	.000	.016	.770	.663	.025	.292	.473	.025		.029	.313	.000
Self-Evaluated Factors	Pearson Correlation	-.175*	.026	-.010	-.056	-.131	.026	-.031	-.103	.046	-.030	-.159*	1	.146*	.272**
	Sig. (2-tailed)	.016	.723	.896	.449	.073	.725	.677	.159	.529	.680	.029		.046	.000
Localised Body Part Factors	Pearson Correlation	-.323**	.026	-.102	-.082	-.068	.008	-.256**	.122	.013	.123	.074	.146*	1	.345**
	Sig. (2-tailed)	.000	.722	.165	.264	.351	.910	.000	.095	.857	.093	.313	.046		.000
TE Sensation Factors	Pearson Correlation	-.493**	-.012	.138	-.012	.196**	.005	-.215**	-.240**	.010	.058	-.278**	.272**	.345**	1
	Sig. (2-tailed)	.000	.869	.058	.866	.007	.945	.003	.001	.891	.433	.000	.000	.000	

Table 4.2(h): Correlation between Localised Body Parts and Perceived Thermal Sensation Variables.

		Body Part A	Body Part B	Body Part C	Body Part D	Body Part E	Body Part F	Body Part G	Body Part H	Body Part I	Body Part J	Body Part K	Gender	TS
Body Part A	Pearson Correlation	1	.693**	.466**	.474**	.233**	.231**	.260**	.109	.380**	.234**	-.108	-.144*	-.021
	Sig. (2-tailed)		.000	.000	.000	.001	.001	.000	.138	.000	.001	.139	.048	.778
Body Part B	Pearson Correlation	.693**	1	.652**	.476**	.269**	.205**	.316**	.013	.274**	.205**	-.037	-.360**	-.159*
	Sig. (2-tailed)	.000		.000	.000	.000	.005	.000	.859	.000	.005	.616	.000	.029
Body Part C	Pearson Correlation	.466**	.652**	1	.160*	.364**	.331**	.393**	.034	.245**	.403**	.187*	-.287**	-.302**
	Sig. (2-tailed)	.000	.000		.028	.000	.000	.000	.648	.001	.000	.010	.000	.000
Body Part D	Pearson Correlation	.474**	.476**	.160*	1	.441**	.203**	.134	.046	.239**	.031	-.196**	-.207**	.017
	Sig. (2-tailed)	.000	.000	.028		.000	.005	.068	.530	.001	.677	.007	.004	.815
Body Part E	Pearson Correlation	.233**	.269**	.364**	.441**	1	.617**	.276**	.138	.126	.269**	.083	-.274**	-.194**
	Sig. (2-tailed)	.001	.000	.000	.000		.000	.000	.059	.085	.000	.257	.000	.008
Body Part F	Pearson Correlation	.231**	.205**	.331**	.203**	.617**	1	.352**	.208**	.284**	.437**	.347**	-.258**	-.284**
	Sig. (2-tailed)	.001	.005	.000	.005	.000		.000	.004	.000	.000	.000	.000	.000
Body Part G	Pearson Correlation	.260**	.316**	.393**	.134	.276**	.352**	1	.398**	.405**	.402**	.146*	-.046	-.237**
	Sig. (2-tailed)	.000	.000	.000	.068	.000	.000		.000	.000	.000	.045	.528	.001
Body Part H	Pearson Correlation	.109	.013	.034	.046	.138	.208**	.398**	1	.363**	.325**	.346**	.082	-.277**
	Sig. (2-tailed)	.138	.859	.648	.530	.059	.004	.000		.000	.000	.000	.261	.000
Body Part I	Pearson Correlation	.380**	.274**	.245**	.239**	.126	.284**	.405**	.363**	1	.680**	.236**	-.019	-.106
	Sig. (2-tailed)	.000	.000	.001	.001	.085	.000	.000	.000		.000	.001	.795	.148
Body Part J	Pearson Correlation	.234**	.205**	.403**	.031	.269**	.437**	.402**	.325**	.680**	1	.535**	-.037	-.247**
	Sig. (2-tailed)	.001	.005	.000	.677	.000	.000	.000	.000	.000		.000	.619	.001
Body Part K	Pearson Correlation	-.108	-.037	.187*	-.196**	.083	.347**	.146*	.346**	.236**	.535**	1	-.044	-.415**
	Sig. (2-tailed)	.139	.616	.010	.007	.257	.000	.045	.000	.001	.000		.553	.000
Gender	Pearson Correlation	-.144*	-.360**	-.287**	-.207**	-.274**	-.258**	-.046	.082	-.019	-.037	-.044	1	.124
	Sig. (2-tailed)	.048	.000	.000	.004	.000	.000	.528	.261	.795	.619	.553		.089
TS	Pearson Correlation	-.021	-.159*	-.302**	.017	-.194**	-.284**	-.237**	-.277**	-.106	-.247**	-.415**	.124	1
	Sig. (2-tailed)	.778	.029	.000	.815	.008	.000	.001	.000	.148	.001	.000	.089	

Table 4.2(i): Correlations of Work Nature and Perceived Thermal Sensation Variables.

		Work Nature	Level of Coldness	Level of Humidity	Level of Freshness	Level of Airflow	Level of Sleepiness	Concentration	TS	Sweat Rate	Effort Needed	Productivity
Work Nature	Pearson Correlation	1	.184*	-.221**	-.073	-.080	.005	.097	-.066	-.014	.057	-.044
	Sig. (2-tailed)		.012	.002	.319	.273	.947	.186	.371	.844	.435	.547
Level of Coldness	Pearson Correlation	.184*	1	-.227**	.252**	.184*	-.164*	-.200**	-.389**	-.018	.254**	.141
	Sig. (2-tailed)	.012		.002	.000	.012	.024	.006	.000	.811	.000	.053
Level of Humidity	Pearson Correlation	-.221**	-.227**	1	-.189**	-.085	.075	-.107	.159*	-.045	-.001	.032
	Sig. (2-tailed)	.002	.002		.009	.247	.305	.142	.029	.539	.989	.667
Level of Freshness	Pearson Correlation	-.073	.252**	-.189**	1	.613**	-.185*	-.131	-.314**	.154*	.129	.240**
	Sig. (2-tailed)	.319	.000	.009		.000	.011	.073	.000	.035	.078	.001
Level of Airflow	Pearson Correlation	-.080	.184*	-.085	.613**	1	-.175*	-.121	-.374**	.082	.272**	.297**
	Sig. (2-tailed)	.273	.012	.247	.000		.016	.099	.000	.261	.000	.000
Level of Sleepiness	Pearson Correlation	.005	-.164*	.075	-.185*	-.175*	1	.629**	.029	-.152*	-.232**	-.328**
	Sig. (2-tailed)	.947	.024	.305	.011	.016		.000	.688	.037	.001	.000
Concentration	Pearson Correlation	.097	-.200**	-.107	-.131	-.121	.629**	1	.017	-.126	-.394**	-.475**
	Sig. (2-tailed)	.186	.006	.142	.073	.099	.000		.817	.084	.000	.000
TS	Pearson Correlation	-.066	-.389**	.159*	-.314**	-.374**	.029	.017	1	-.109	-.243**	-.206**
	Sig. (2-tailed)	.371	.000	.029	.000	.000	.688	.817		.137	.001	.005
Sweat Rate	Pearson Correlation	-.014	-.018	-.045	.154*	.082	-.152*	-.126	-.109	1	.219**	.352**
	Sig. (2-tailed)	.844	.811	.539	.035	.261	.037	.084	.137		.003	.000
Effort Needed	Pearson Correlation	.057	.254**	-.001	.129	.272**	-.232**	-.394**	-.243**	.219**	1	.762**
	Sig. (2-tailed)	.435	.000	.989	.078	.000	.001	.000	.001	.003		.000
Productivity	Pearson Correlation	-.044	.141	.032	.240**	.297**	-.328**	-.475**	-.206**	.352**	.762**	1
	Sig. (2-tailed)	.547	.053	.667	.001	.000	.000	.000	.005	.000	.000	

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).